



**New
Scientist**

ESSENTIAL GUIDE **Nº4**

WHERE WE CAME FROM
WHO OUR ANCESTORS WERE
HOW HUMANS SPREAD
ACROSS THE WORLD
THE LOST "OTHERS"
AND MORE

OUR HUMAN STORY

HOW ONE SPECIES
WALKED UPRIGHT
AND CONQUERED
THE WORLD

EDITED BY
KATE DOUGLAS





NEW SCIENTIST ESSENTIAL GUIDE OUR HUMAN STORY

THE human story starts somewhere in Africa with one ape learning to walk upright, and ends with one of their descendants dominating the world. It is a fascinating, yet frustratingly incomplete, tale – and one that seems to gain added complexity every time a new fossil bone or piece of DNA evidence is found.

As with its three predecessors in the *Essential Guide* series, this volume is curated from the best content from *New Scientist*'s recent archive, specially revised and updated to bring you up to speed with the latest developments. It covers a lot of ground, from our earliest African origins to a discussion of some of the qualities, such as our morality, our art and our language, that have made us uniquely successful.

To that list we might add our talent for navel gazing. In that spirit, I hope you enjoy this overview of the story of our species. Don't forget, if you missed previous editions of the *Essential Guides*, they are all available to buy online at shop.newscientist.com. And if you don't want to miss a further issue, all the *Essential Guides* are available on subscription at newscientist.com/essentialguide. Feedback is welcome at essentialguides@newscientist.com. *Kate Douglas*

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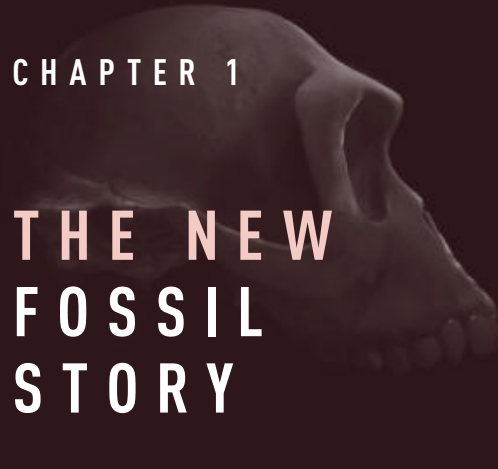
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CHAPTER 1

THE NEW FOSSIL STORY

Fossil finds have traditionally been the foundation on which we built our understanding of the human story. But, over the past few years, some extraordinary finds have called into question almost every assumption we had made about how long we have walked on Earth, who our ancestors were and where we really come from.

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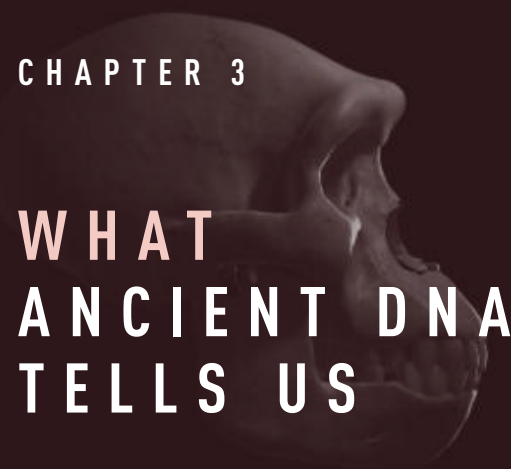


CHAPTER 2

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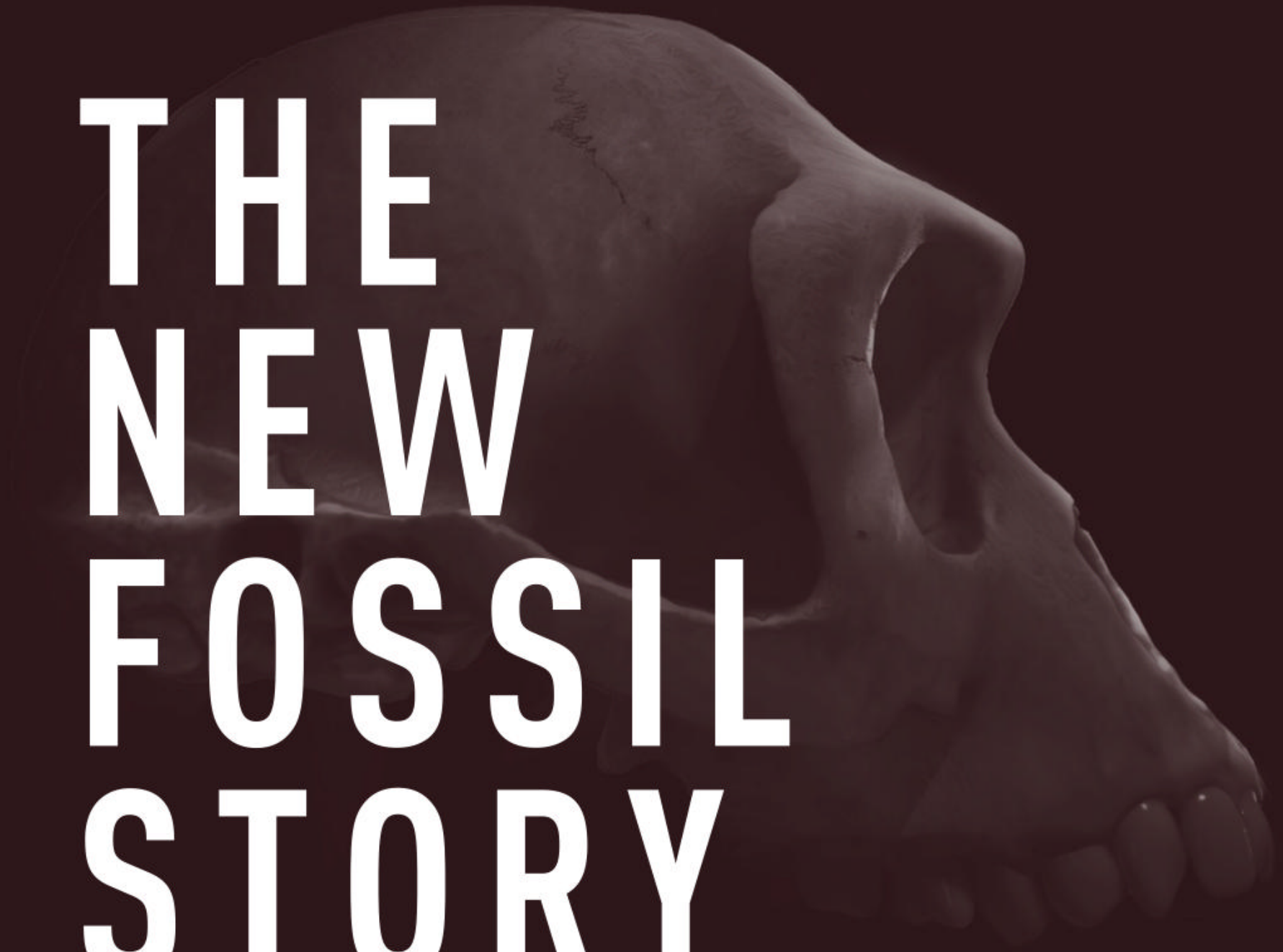
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CHAPTER 1



THE NEW FOSSIL STORY

Fossil finds have traditionally been the foundation on which we built our understanding of the human story. But, over the past few years, some extraordinary finds, including of physical remains from ancestors we never even imagined might exist, have called into question almost every assumption we had made.

Our understanding is still far from complete, but the new insights have unsettling implications for how long we have walked on Earth, who our ancestors were and where we really come from, and, indeed, who we even are. Our new human story starts here.

BONES OF CONTENTION

Who do we think we are? Modern humans, descended from a long line of *Homo sapiens*? Distant relatives of those great adventure-seekers who marched out of the cradle of humanity, Africa, 60,000 years ago? Members of a species whose origins can be traced back to a common ancestor with chimpanzees? The sole survivor of a lineage of apes whose brains have been getting progressively bigger for millions of years? Whatever answer we might be tempted to give, new fossil finds suggest the true tale of our origins is a lot more complex.

PREVIOUS PAGE: SCIENCE PICTURE CO/ALAMY
RIGHT: NATIONAL GEOGRAPHIC IMAGE COLLECTION/ALAMY

ONCE upon a time, the human story seemed relatively straightforward. It began some 6 million years ago in an east African forest, with a chimpanzee-like ape. Some of its descendants would eventually evolve into modern chimps and bonobos. Others left the forest for the savannah. They learned to walk on two legs and, in doing so, launched our own lineage, the hominins.

By about 4 million years ago, the story goes, these bipedal apes had given rise to a successful but still primitive group called the australopiths, thought to be our direct ancestors. The most famous of them, dubbed Lucy, was discovered in the mid-1970s and given arch-grandmother status. By 2 million years ago, some of her descendants had grown larger brains and longer legs to become the earliest members of the genus we belong to, *Homo*. Among the first of these species was *Homo erectus*, which used its long legs to march out of Africa. Other hominins continued to evolve larger brains in an apparently inexorable fashion, with new waves of bigger-brained species migrating out of Africa over the next million years or so, eventually giving rise to the Neanderthals of Eurasia. ➤



Ultimately, however, those early migrant lines were all dead ends. The biggest brains of all evolved in those hominins who stayed in Africa, and they were the ones who gave rise to *Homo sapiens*. Our great march out of Africa began 60,000 years ago and by 30,000 years ago, for whatever reason, every other contender was extinguished. Only *H. sapiens* remained – a species with a linear history stretching some 6 million years back into the African jungle. Or so we thought.

Starting in the early 2000s, a tide of new discoveries began adding layer upon layer of complexity and confusion to this neat narrative and rewriting many of the key plot twists.

→
There's more detail on the complex origins of *Homo sapiens* in chapter 2

First, in 2001, excavations in Chad revealed a new hominin species, *Sahelanthropus tchadensis*, dating back to a virtually unknown period of human prehistory. Rough genetic calculations had led us to believe the split from the chimp lineage occurred between 5.5 and 6.5 million years ago. The *S. tchadensis* fossil dated from around 7 million years ago, and it looked more like us than modern chimps do. The anatomy of the back of its skull even suggested the head sat on top of a vertical spine like that of a human, hinting at an upright stance. Our lineage might be at least half a million years older than we thought.

However, so few *S. tchadensis* fossils have been found that some palaeoanthropologists still question

whether it is a hominin rather than some other type of ape. Geneticists made grumpy noises at first, too, claiming the bone studies were wrong. But a decade later, their own analysis pushed the origins of our lineage back further still. In 2012, revised ideas about how quickly genetic differences accumulate in our DNA forced a reassessment of the original calculation. Its conclusion: the human-chimp split could have occurred between 13 and 7 million years ago.

→
Chapter 3 has a lot more on new genetic insights into our ancestry

Today, there is no longer a clear consensus on how long hominins have walked the earth. Many are sticking with the old assumption, but others are willing to consider the possibility that our lineage could be twice as old, implying there are plenty of missing chapters to our story still waiting to be uncovered.

That's just the start of the story. A second upset throws doubt on the next key step in human evolution. One of the oldest ideas in the textbooks is that our four-legged ancestors abandoned the forests, perhaps because of a change in climate conditions, and then adapted to walk on two legs. Known as the savannah hypothesis, it was first proposed by Jean-Baptiste Lamarck in 1809. Exactly 200 years later, an exquisite, exceptionally preserved 4.4-million-year-old skeleton was unveiled to the world, challenging that hypothesis.

"Ardi" is a member of a species called *Ardipithecus ramidus*, which was first unearthed in the 1990s. She is



The “Ardi” fossil contradicts the idea that our ancestors only walked upright after they left the forests

a jewel in the hominin fossil record, and all the more important because of the number of key assumptions she casts doubt on. Ardi didn’t have a chimp’s adaptations for swinging below branches or knuckle-walking, suggesting chimps gained these features relatively recently. In other words, the ape that gave rise to chimps and humans may not have been chimp-like after all. Instead, Ardi’s feet, legs and spine clearly belonged to a creature that was reasonably comfortable walking upright. Yet, according to her discoverers, she lived in a wooded environment. This suggests that hominins began walking on two legs before they left the forests, not after – directly contradicting the savannah hypothesis.

Although not everyone is convinced that Ardi was a forest-dweller, other lines of evidence also suggest we have had the upright walking story back to front all these years. We now know, for example, that orangutans in their natural environment stand on two legs to walk along branches, giving them better access to fruit. In fact, all living species of great ape will occasionally walk on two legs as they move around the forest canopy. It would almost be odd if our own ancestors had not.

Whether before or after standing on two legs, at some stage our ancestors must have come down from the trees. We can depend on that, at least. Entering the 21st century, we knew of just one group that fitted this transition stage: the australopiths, a genus of ape-like bipedal hominins, known from fossils found largely in east Africa and dating to between 4.2 and 1.2 million years ago. They lived in the right place at the right time

to have evolved into our genus *Homo* just before 2 million years ago. Lucy would have showed up in the middle of that period, 3.2 million years ago. A direct ancestor who lived in east Africa’s Rift Valley, since her discovery, she has served as a reassuring foundation stone on which to build our hominin family tree.

Then, in 2001, researchers unveiled a 3.5-million-year-old skull discovered in Kenya. It should have belonged to Lucy’s species, *Australopithecus afarensis*, the only hominin thought to be living in east Africa at the time. But its face didn’t fit. It was so flat that it could barely be considered an australopith, says Fred Spoor at University College London, who analysed the skull. He and his colleagues gave it a new name reflecting its flat-faced appearance: *Kenyanthropus platyops*.

On the face of it, the suggestion that Lucy’s species shared east Africa with a completely different type of hominin seemed only of marginal interest. But within a few years, the significance of *Kenyanthropus* began to grow. After comparing the skull’s features with those of other hominin species, some researchers dared to suggest that *K. platyops* was more closely related to us than any australopith species. The conclusion pushed Lucy onto a completely different branch of the family tree, robbing her of her arch-grandmother position.

If that wasn’t confusing enough, other researchers were making a similar attack from a different direction. Another new species of hominin, also discovered in Kenya in 2001, looked more human-like than the australopiths too. *Orrorin tugenensis* is known from just 13 fragmentary fossils including three partial thigh bones. Most research has focused on one of these, ➤

“We were trying to tell the human story too early, on too little evidence”

and whether it shows that *O. tugenensis* walked upright. Although there are some sceptics, many experts believe that the species was at least beginning to become bipedal. That is extraordinary, given that *O. tugenensis* is 6 million years old.

While some researchers see these newly discovered hominins as more likely to be our direct ancestor than Lucy or her kin, most remain unconvinced by these ideas, says Spoor. And the more recent discovery of a 2.8-million-year-old human-like jawbone in Ethiopia consolidates Lucy’s position. “In many respects it’s an ideal transitional fossil between *A. afarensis* and earliest *Homo*,” says Spoor. Nevertheless, Lucy’s status as our direct ancestor has been formally challenged, twice, and it’s not inconceivable that the strength of these or other challenges will grow.

Intriguingly, in 2015, a team announced the discovery of the oldest known stone tools. The 3.3-million-year-old artefacts were found in essentially the same deposits as *Kenyanthropus*. Perhaps that hints at a tool-making connection between *Kenyanthropus* and early members of the genus *Homo* – although there is circumstantial evidence that some australopiths used stone tools too. In any event, determining which hominins evolved into humans is no longer as clear-cut as it once was. Indeed, some believe this key step might not even have happened in east Africa, the area long assumed to be the cradle of humanity.



Turn to page 52 for more on how and when humans left Africa

Then there are the fossils found in South Africa. In the past decade, two bizarre species have been unearthed. *Australopithecus sediba* and *Homo naledi* are quite unlike any hominin discovered before, says Lee Berger at the University of Witwatersrand in South Africa, who led the analysis of both. Their skeletons seem almost cobbled together from different parts of unrelated hominins. Significantly, the mishmash of features in the *A. sediba* skeleton, unveiled in 2010, is very different from those in the *H. naledi* skeleton, unveiled in 2015. *A. sediba*’s teeth, jaws and hands were human-like while its feet were ape-like. *H. naledi*, meanwhile, combined australopith-like hips with the skull of an early “true” human and feet that were almost indistinguishable from our own.



There’s a profile of Lee Berger with more on his discoveries later in this chapter

What’s particularly significant is the ages of these two South African species. *H. naledi* is 236,000 to 335,000 years old, putting it on the cusp of the evolution of our own species *H. sapiens*. Meanwhile, *A. sediba* has been dated to 2 million years old – just the time when the genus *Homo* emerged. Berger believes its hotchpotch of anatomical features mean that it was becoming human, indicating that the first members of our genus, *Homo*, evolved in South Africa.

Others who have examined the *A. sediba* fossils are not convinced, concluding that they may be from two different species. But Berger points out that very few

other ancient hominins are preserved in so much detail as *A. sediba* and *H. naledi* – and no other ancient species seems quite as strange. Perhaps that’s just an interesting coincidence or perhaps, he says, it’s a sign that we have oversimplified our understanding of hominin evolution. We tend to assume that ape-like species gradually morphed into human-like ones over millions of years. In reality, there may have been a variety of evolutionary branches, each developing unique suites of advanced human-like features and retaining a distinct array of primitive ape-like ones. “We were trying to tell the story too early, on too little evidence,” says Berger. “It made great sense right up until the moment it didn’t.”

That’s just the story of human evolution within Africa. Discoveries outside the continent in the 21st century are equally paradigm busting. We have long assumed that the only hominins to leave Africa had big-brains and long legs, with *H. erectus* thought to be the pioneer. Evidence chipping away at this idea began to emerge in 2002 with the discovery of a 1.75-million-year-old human skull that would have housed a brain of no more than 600 cubic centimetres, about half the size of modern human brains. Such a fossil wouldn’t be an unusual find in east Africa, but this one turned up at Dmanisi in Georgia, in the Caucasus region. Clearly, small-brained hominins had left Africa.

In other respects, the Dmanisi skull and several others found at the site did not threaten the standard narrative: they are perhaps just small-brained versions of *H. erectus*. But a discovery in 2003 would prove far more problematic. That year, researchers working on

the Indonesian island of Flores found yet another bizarre skeleton. It had the small brain and small body of an early African hominin from around 2 to 3 million years ago. Yet, it seemed to have been alive up until just a few tens of thousands of years ago in a region thought to be home only to long-limbed and large-brained hominins. The team named the peculiar species *Homo floresiensis*. Most people know it by its nickname: the hobbit.



Find out more about the hobbit and co. on page 79

“I said in 2004 that I would have been less surprised if they had found an alien spacecraft on Flores than *H. floresiensis*,” says Peter Brown at the Australian National University, who led the analysis of the remains. The primitive-looking skeleton was, and still is, “out of place and out of time”. There is no agreement on the hobbit’s significance, but one leading idea is that it is evidence of a very early migration out of Africa involving prehuman australopith-like hominins.

In 2019, palaeoanthropologists announced that they had found another hobbit-like species some 5000 kilometres to the north of Flores on the Philippine island of Luzon. Some of fossils are some 50,000 years old, making it around the same age as the hobbit. Two decades ago, such a find would have been front-page news. It is a sign of how profoundly and regularly orthodox ideas about human evolution have been challenged in recent years that the discovery of *Homo luzonensis* hardly registered with most people. ■

REWRITING OUR TIMELINE

In the early 2000s, the standard story of how we evolved from a chimp-like ancestor seemed linear and logical. Then came **two decades of relentless and confounding discoveries**

7 MILLION YEARS AGO

EURASIA

6 MYA

The common ancestor of chimps and humans lives in the forests of east Africa

5 MYA

Some of these early apes come down from the trees, stand up on two legs and walk out into the savannah

4 MYA

They give rise to australopiths including Lucy (*Australopithecus afarensis*)

3 MYA

Hominin species diversify. Some evolve bigger brains and longer legs to become early humans

AFRICA

7 MYA

SAHELANTHROPUS TCHADENSIS
(ANNOUNCED 2002)

Strange ape skull with some human-like features suggests our ancestors split from chimps more than 7mya

4.4 MYA

"ARDI" ARDIPITHECUS RAMIDUS
(2009)

Ardi walked on two legs but may have lived in woods, suggesting hominins first walked upright in forests

6 MYA

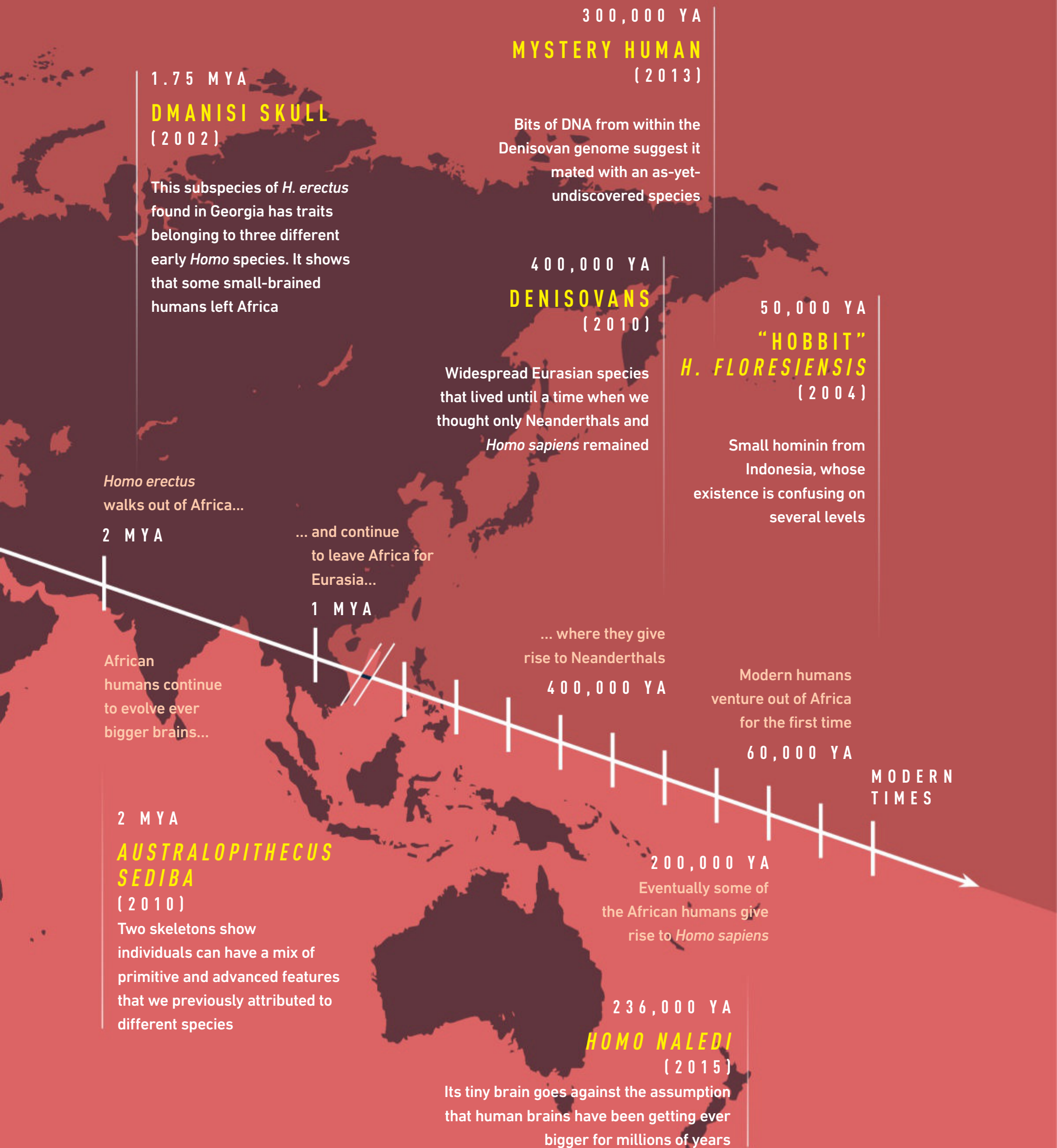
ORRORIN TUGENENSIS
(2001)

Species the size of a chimp with human-like teeth. Its thigh bone suggests it was bipedal. Some say it may be closer to modern humans than Lucy

3.5 MYA

KENYANTHROPUS PLATYOPS
(2001)

Contemporary with Lucy's species. Some say it was closer to modern humans than australopiths



300,000 YA

MYSTERY HUMAN

(2013)

Bits of DNA from within the Denisovan genome suggest it mated with an as-yet-undiscovered species

400,000 YA

DENISOVANS

(2010)

Widespread Eurasian species that lived until a time when we thought only Neanderthals and *Homo sapiens* remained

50,000 YA

"HOBBIT"

H. FLORESIENSIS

(2004)

Small hominin from Indonesia, whose existence is confusing on several levels

Homo erectus walks out of Africa...

2 MYA

... and continue to leave Africa for Eurasia...

1 MYA

African humans continue to evolve ever bigger brains...

... where they give rise to Neanderthals

400,000 YA

Modern humans venture out of Africa for the first time

60,000 YA

MODERN TIMES

2 MYA

AUSTRALOPITHECUS SEDIBA

(2010)

Two skeletons show individuals can have a mix of primitive and advanced features that we previously attributed to different species

200,000 YA

Eventually some of the African humans give rise to *Homo sapiens*

236,000 YA

HOMO NALEDI

(2015)

Its tiny brain goes against the assumption that human brains have been getting ever bigger for millions of years

THE EARLIEST HUMANS

Around 2 million years ago, some hominins began to evolve key traits that we associate with humans. We put them in a new genus, *Homo*. But our ideas about the early *Homo* species are changing – as is the notion that hominins became progressively more sophisticated until our species eventually emerged.

BY THE middle of the 20th century, researchers were beginning to accept that humans evolved in Africa from an ancient group of “ape people” called the australopiths. In 1960, a research team at Olduvai Gorge in Tanzania found fossil remains of a species that seemed to fall in the gap between the australopiths and humans. It originated sometime before 2 million years ago and was extinct by around 1.5 million years ago. The researchers identified it as the first true human species to evolve – the original member of our genus *Homo* – and they named it *Homo habilis*.

From the fragmentary fossils found, *H. habilis* seemed to have had a brain substantially larger than an australopith’s and more like that of later human species. What’s more, according to its discoverers, *H. habilis* behaved in a human-like way too. They suggested it produced stone tools, while the australopiths apparently did not. This feature was so important it even explains the name they chose for the species – *H. habilis* translates roughly as “handy man”.

However, in the decades since its discovery, *H. habilis* has become a controversial species. Some researchers think it was actually an australopith, given that it doesn’t seem to have been adapted to long-distance walking, which is arguably a defining human feature. Its tool-making skills are seen as less significant too, because it is now clear that australopiths also produced stone tools.

Nevertheless, one population of *H. habilis* might

have evolved into the earliest indisputable human species – *Homo erectus* (upright man). Discovered back in 1891, *H. erectus* might be less well known than other extinct humans like the Neanderthals, but it was an immensely important species. Unlike *H. habilis*, there is no doubting that *H. erectus* looked and behaved in a human-like way. It probably evolved in Africa, about 2 million years ago, and using its long legs, it quickly expanded across Eurasia, making it the earliest human species known to have migrated long distances.



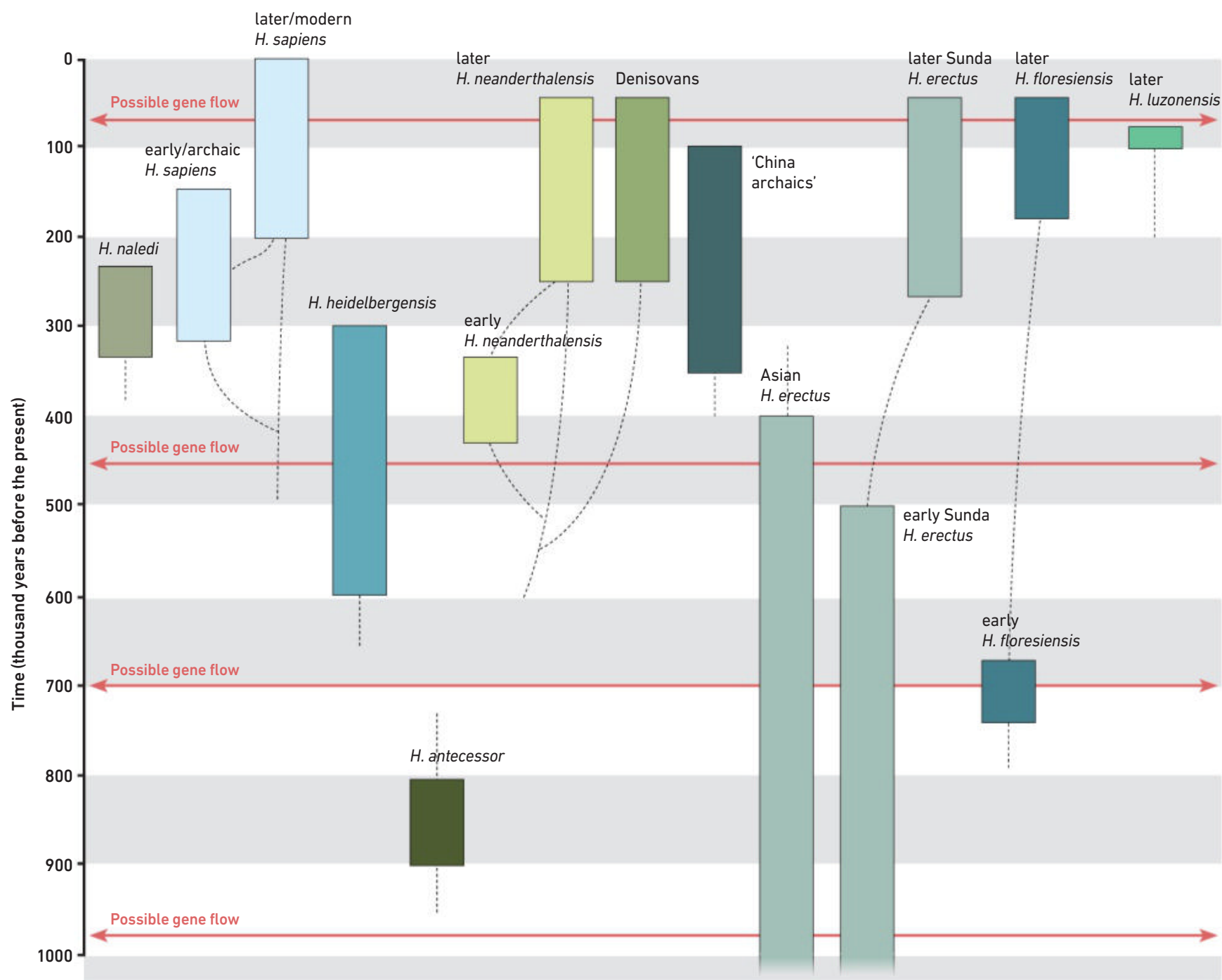
Turn to chapter 4 for more on our migratory history, and chapter 5 for more on “other” humans

H. erectus was probably also the earliest human to learn how to control fire. It may have been the first to cook food too – an innovation some people think may have helped *H. erectus* and its descendants improve the nutritional quality of their diet, opening the way for the evolution of larger, energy-demanding brains that fuelled the emergence of even more sophisticated behaviour. The date of its extinction is much debated: late evidence for the persistence of *H. erectus* in the Indonesian Sunda islands suggest it and our own species, *Homo sapiens*, shared the planet for perhaps hundreds of thousands of years (see diagram, right).

While *H. erectus* inhabited Eurasia, there is another early member of the *Homo* genus that may have lived alongside us in Africa. We’ve already encountered *Homo naledi* (star man), discovered in South Africa in 2013. Because its skeleton shows such a strange mix of modern and ancient features, it is still not clear where it belongs in the human evolutionary tree. One study suggests it might sit on a branch very near the bottom, perhaps somewhere between *H. habilis* and *H. erectus*. As such, many people anticipated that *H. naledi* lived at roughly the same time as *H. habilis*, and probably went extinct more than a million years ago as more advanced humans like *H. erectus* outcompeted it. But *H. naledi* seems to have been alive until as recently as 250,000 years ago.

What makes *H. naledi* particularly significant is its ability to undermine some of our most deeply held

Palaeoanthropologists currently recognise as many as nine human species that have existed in the past million years – as well as the “China archaics”, whose status is not yet certain. How these species interrelate is still unclear, although some lineages are reasonably well established (dotted lines) and other patterns of gene flow between species at different times are becoming more apparent (red lines)



SOURCE: CHRIS STRINGER

ideas about how human-like behaviour evolved. Some parts of its skeleton are indistinguishable from those of living people while other parts looked almost ape-like. It also had a brain little bigger than that of a chimpanzee. Yet, tantalising but controversial evidence suggests that *H. naledi* intentionally disposed of its dead – perhaps a sign that even “primitive” hominins could behave in an apparently sophisticated way. Ritual burial has long been considered a hallmark of symbolic thinking, which in turn underpins some

of the abilities, such as language and art, that most strongly differentiate humans from other species.

H. naledi's relatively young age is a striking example of how complex and confusing the human evolutionary tree might really be. Human brains didn't grow and grow for millennia, with smaller-brained species falling to the wayside of the gradual evolutionary road, as we had until recently assumed. Instead, our species occupied an African landscape that was also home to humans with brains half the size of theirs. ■

FOUR RARE EARLY ANCESTORS

Some of our ancestors are known only by small fossils: a toe bone here, a jaw fragment there. In those cases, it is all we have to build the story of human evolution. The following four early African hominins are some of the rarest of all. If and when we find more evidence, maybe their stories will change the most.

WAS IT AN APE?

SAHELANTHROPUS TCHADENSIS

Of all possible hominins found so far in Africa, *S. tchadensis* is the most ancient, at about 7 million years old. Officially, it is known only from a handful of fossils found in Chad in 2001: a few teeth, parts of two lower jaws and, most importantly, a single, relatively complete skull.

Features at the skull's rear suggest it sat atop a vertical spine like that of a human, hinting that *S. tchadensis* walked upright. To make sure, other fossils will be needed – particularly from the legs. Unconfirmed reports suggest that a thigh bone was found with the skull, but this has not yet been discussed in a scientific paper. With so little evidence to go on, some are sceptical that *S. tchadensis* can really yet be defined as a hominin rather than some other form of ape – yet.

THE THIGH BONE'S CONNECTED TO THE...?

ORRORIN TUGENENSIS

Discovered in western Kenya, largely in 2000, *O. tugenensis* is officially known from a baker's dozen of fossils, six of which are teeth. The others include a finger bone, two jaw fragments, parts of three thigh bones and a fragment of an upper arm bone. Most research has focused on one of the thigh bones, and whether it shows that *O. tugenensis* walked upright on two legs. Many argue that this 6 million year old hominin was at least beginning to become bipedal. More fossil evidence could settle the matter.

A FACE FOR TOOL-MAKING?

KENYANTHROPUS PLATYOPS

Unearthed in 3.3-million-year-old deposits in north-west Kenya, in the late 1990s, *K. platyops* is best known from a largely complete but squashed and distorted skull. A few dozen other fossil fragments were found at the same time – mostly teeth, but also pieces of a second skull, and parts of a few upper and lower jaws.

All the *K. platyops* fossils found so far come from above the neck, so we do not know what its body looked like or was capable of. However, very primitive stone tools were later found in the same rocks. *K. platyops* might have made these, but one researcher has suggested that the tool-maker could instead have been a hominin called *Australopithecus deyiremeda* – another enigmatic species known from no more than a few jaw fragments.

IS IT EVEN A SPECIES?

HOMO RUDOLFENSIS

Most researchers believe that the genus we belong to, *Homo*, emerged in Africa between 2 and 3 million years ago – but there is no agreement on how many *Homo* species shared the landscape. *H. rudolfensis* sits at the centre of the controversy.

For decades, *H. rudolfensis* was known only from a distinctive 1.9-million-year-old large-brained, flat-faced skull discovered in 1972 in Kenya. Three additional face and jaw fossils found in Kenya between 2007 and 2009 helped confirm to some researchers that the 1972 skull really did belong to a distinct species – but others are sceptical.

Even the species name is controversial: it was established in the late 1970s by a Russian researcher not involved in the discovery of the 1972 skull. The researchers who analysed the three more recently found fossils say we need more fossil material before we can confirm whether the *H. rudolfensis* name is valid – or whether the species really belongs in our genus. ■

HOW TO DATE A FOSSIL

The discovery of weird bones in strange places seems to be the new normal in palaeoanthropology. But, interpreting these physical remains is not easy. As well as comparing the anatomy of different specimens, fossils must also be dated. Until recently, our ability to do this was limited.

THE age of a fossil can be inferred from the age of the sediments in which it is found, and the plants, animals and tools associated with it. But bones may have been buried in a grave or eroded out of older sediments and redeposited. Worse, critical stratigraphic information has been lost for around 90 per cent of the hominin specimens that have been found, because they were excavated before rigorous archaeological techniques became the norm in recent decades. “If you want to know how old fossil hominins are, you have to date them directly,” says Rainer Grün of Griffith University in Queensland, Australia, who has been involved in dating many of the hominin fossils that have rewritten our understanding of human evolution.

Long the only method of dating specimens directly, carbon-14 dating relies on the fact that living organisms incorporate the three isotopes of carbon – carbon-12, carbon-13 and carbon-14 – into their tissues at the relative levels found in the atmosphere. When an organism dies, it no longer incorporates carbon. The unstable carbon-14 gradually decays to nitrogen, reducing the amount of carbon-14 present in the fossil compared with carbon-12 and carbon-13. It takes 5730 years for half of the carbon-14 in a sample to decay, so

measuring the ratio of carbon isotopes gives an estimate of when an organism died, give or take a few hundred years. Unfortunately, the short carbon-14 half-life means that carbon dating can go back a maximum of 55,000 years and usually no more than 45,000. That limits its usefulness for studying human evolution.

Enter two newer techniques: electron spin resonance (ESR) and uranium series (U-series) dating. ESR is invaluable for dating teeth, which because of their physical properties preserve far more easily than bone. It exploits the fact that enamel is full of a mineral called hydroxyapatite, which contains lots of ions that, when zapped by background radiation, form free radicals. These accumulate over time and can be measured by various spectroscopic techniques. This method can indicate the age of a tooth up to 3 million years old, says Grün.

U-series dating, meanwhile, builds on the observation that living bones contain almost no uranium, thorium or lead. Once buried, however, bones absorb uranyl ions from water in soil or sediments, and the uranium in these then decays to thorium and lead via predictable pathways. So the ratios of the three elements can indicate how long something has been buried. Uranium’s long half-life (around 245,000 years) means that U-series dating can easily go back 500,000 years or more. ■

PROFILE: LEE BERGER

A 21ST-CENTURY FOSSIL HUNTER

A flurry of activity and new discoveries in the mid-20th century, when palaeoanthropologists Louis and Mary Leakey began excavations in East Africa, led to the crucial realisation that Africa was the cradle of humanity. Yet by the end of the century, few new hominin fossils were being found, and there was a growing belief that there was little left to discover.

That has made the abundance of significant new finds made this century truly surprising. Many are now working in the field, but nobody epitomises the new energy and enthusiasm for the fossil hunt more than Lee Berger. He is behind the discovery of not one, but two new species of human ancestor – finds that have made him a far from an uncontroversial figure.

IN 2010, palaeoanthropologist Lee Berger made headlines after he (or, more accurately, his then 9-year-old son) found a trove of hominin bones belonging to a species we now know as *Australopithecus sediba* in the hills north of Johannesburg. It was the sort of once-in-a-lifetime find that most people in his line of work only dream of. If Berger had taken the conventional approach, he might have built the rest of his career on analysing it. But following convention was not what Berger, an American who made South Africa his home three decades ago, had in mind. He was convinced that even greater discoveries were waiting, particularly in the ancient caves that riddle the limestone-rich countryside in his back yard. He enlisted local help to search them, and hit the jackpot in 2013: two chambers deep inside the Rising Star cave system contained hundreds of bones from another unknown species, which his team dubbed *Homo naledi*. This time, the story went stratospheric, for the find's scale and drama. One of the chambers is at the bottom of a 12-metre vertical passage just 20 centimetres across at some points. Berger recruited a team of very slim, palaeoanthropologist cavers to excavate the site. The fact that all of them were women created even more publicity.

Publicity is something Berger has never shied away from, indeed he courts it. It's just one of the reasons why, over the years, he has managed to upset and dismay an impressive number of his peers, ➤

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“It was a huge hoard: most hominin species exist only as a handful of bones”

including some of the most respected figures in the field. The Rising Star excavations were a case in point. Donald Johanson – one of the discoverers of the 3.2-million-year-old Lucy skeleton – claimed the excavation should have taken months, not the 21 days Berger and his colleagues set aside. Berger responded that it was essentially a pilot excavation, although within months his team had submitted several papers to the journal *Nature* based on analysis of the fossils. They weren't accepted.

In person, Berger is chatty, warm and likeable. He is clearly passionate about his subject. He is also open about his motives. In the late 1980s, Berger got his first opportunity to join a dig, in East Africa. Right from the start, he saw himself as an explorer. “I wanted to find fossils, to make discoveries,” he says, “That’s why I went into the field.”

But opportunities in east Africa were limited. Many senior scientists had already staked claims there, he says. South Africa, on the other hand, was relatively unexplored, although hominin fossils had been found there since the 1920s. He was accepted to study for a PhD at the University of the Witwatersrand, Johannesburg, in 1990.

He never left. Berger reasoned that being able to hunt for fossils all year round would boost his chances of discovery. He says the main strategy at the time was to look for baboon fossils, since hominins were often found with them. But he wanted to look underground, not least because hominin fossils had already been found in caves. Ancient people would have made extensive use of the vast subterranean networks, he thinks. “This dolomitic landscape is one of the most stable in the world,” Berger says. “In a sense we’re standing on their land.”

So far, his team has found the remains of *H. naledi* skeletons, of all ages at more than half a dozen sites. It is a huge hoard, particularly because many hominin species exist only as a handful of bones. “There was a real perception that these fossils are rare,” he says – and those who found them became reluctant to share access to such precious objects. “I’ve watched scientists become possessive,” he says. “I vowed early on not to do that if my opportunity arose.”

His critics see things differently. They argue that they work on the fossils behind closed doors not out of a sense of ownership but to make sure their published conclusions are solid. Tim White – a co-discoverer of the 4.4-million-year-old “Ardi” skeleton – has insisted that good research can’t be rushed.



For the wider fossil story turn back to page 6

Yet scientists in other fields collaborate, Berger says. “It’s what NASA or the Large Hadron Collider team does: they put as many of the best minds in the world towards a solution.” Just months after the first Rising Star excavation, Berger did the same, inviting researchers – particularly young scientists – to a month-long workshop to make sense of the *H. naledi* material. “I’m portrayed as a maverick, as a cowboy scientist,” says Berger. “What’s so funny is that I’m the one following the rules.”

In September 2017, Berger’s team was back at Rising Star. They camped at the site even though it is just a 45-minute drive from Johannesburg: it’s about maximising time in the field, he says. A typical day would start at 5.30 am with breakfast. By 6.30 they would be discussing the day’s objectives, and shortly



2-million-year old *Australopithecus sediba* fossils exhibit some strangely modern features

afterwards the cavers began to inch their way into the chambers. This time, they were looking for evidence that *H. naledi* deliberately disposed of its dead, particularly signs of the fire they would have needed to navigate the deep, dark caves. It is a controversial idea, because the most striking feature of *H. naledi* is that its brain was only marginally larger than a chimpanzee's: much too small, according to conventional thinking, to allow for such advanced behaviour.

Their findings are yet to be published, but the human evolution story is changing in other ways that are making the possibility of a small-brained hominin burying its dead seem less remote. Palaeoanthropologists have in the past assumed a simpler, linear story. This, says Berger, is partly because many ancient hominins are known only from fossil fragments that might fail to reveal just how strikingly weird complete skeletons can be. His copious discoveries do reveal this weirdness. *A. sediba* existed around 2 million years ago, and *H. naledi* may have lived just 235,000 years ago, yet both have a mix of what were previously considered to be primitive and modern features. This might hint that early hominin history involved a lot of evolutionary experimentation, with an array of unusual looking species forming a family tree with many branches.

Berger's enthusiasm is infectious. He is a great storyteller, drawing listeners in and leaving them itching for the next chapter. It's easy to imagine how this might get him in trouble: he does like to push the boundaries of what can be learned from the evidence to hand. But there is so much more evidence waiting to be found, he says. "These hominin fossils are just not as rare as we once thought. We were looking in the wrong places." ■



CHAPTER 2



THE ORIGIN OF OUR SPECIES

The story of the origin of our own species, *Homo sapiens*, once had a neat linearity about it. We evolved in eastern Africa between 200,000 and 150,000 years ago, became capable of modern behaviour some 60,000 years ago and then swept out of Africa to colonise the world, completely replacing any archaic humans we encountered.

The origins of our species do indeed lie in Africa, but discoveries of new fossils and tools, plus analyses of ancient and modern DNA, are tearing apart any neatness to the narrative beyond that. With the dust yet fully to settle, the question now is how many, if any, of our old assumptions still hold.

AFRICA – BUT WHERE AND WHEN?

Much as with the wider story of the emergence of hominins we surveyed in chapter 1, new discoveries are forcing a rethink on almost all fronts when it comes to the origin of our own species, *Homo sapiens*. A simple story built up over recent decades depicted the evolution in relatively short order of a species that resembled us first in body, and then in brain. The reality, it seems, is far messier than that.

FOR most of the 20th century, human origins research was dominated by some early characters in the story: *Homo erectus*, for example, including “Peking Man”, unearthed in 1929, and *Australopithecus afarensis*, the famous “Lucy” discovered in Ethiopia in 1974. There was some debate about where modern humans appeared, and ideas were floating around of a recent African origin. The fossil record, however, seemed to support a model called multiregionalism. This argued that archaic humans were distributed across Africa and Eurasia at least a million years ago and evolved in parallel into modern humans.

Then, in 1987, came a bombshell. A team of geneticists at the University of California, Berkeley, sequenced 147 mitochondrial genomes from living people around the world. The mitochondria in cells are inherited from mothers only, and the study indicated that everyone was descended from a single woman – dubbed “mitochondrial Eve” – who probably lived in Africa about 200,000 years ago.

→ Chapter 3 has more on how DNA reveals our prehistory

The result was very influential. It was quickly consolidated into what is known as the “recent out-of-Africa package”: the idea that modern humans appeared quite abruptly in eastern or southern ➤

Africa some time between 200,000 and 150,000 years ago and went on to conquer the world. The package also introduced the distinction between anatomical and behavioural modernity. Based on archaeological evidence, it looked as though early *Homo sapiens* had bodies like us but weren't as advanced mentally. Only later, about 50,000 or 60,000 years ago, did the full package evolve – perhaps due to a chance mutation – making dispersal out of Africa possible. This tidy, compelling narrative became known as “the human revolution”.



See page 52 for more on when we left Africa

For a while, the fossil evidence obligingly supported this story. Although remains from the crucial time of about 150,000 years ago were absent, there were several older human skulls that seemed to fit the idea.

One of the most distinct features of modern humans is the shape of our heads. Compared with our extinct ancestors, we have small, flat, delicate faces, prominent chins and spherical brain cases. A skull with all or most of these features will generally be classified as belonging to our species. Two of the oldest-known complete skulls with hints of this anatomy were discovered by Richard Leakey and his team at Omo-Kibish in southern Ethiopia in 1967. Known as Omo I and Omo II, they are now dated to about 200,000 years old and have a mixture of archaic and modern features – exactly what you would expect of an archaic African human shortly before the evolution of anatomical modernity. Several other specimens from around eastern and southern Africa told a similar story.

It got even better when, in 1997, palaeontologists in Ethiopia's Afar depression unearthed three human skulls, two adults and a juvenile. The so-called Herto hominins are between 154,000 and 160,000 years old, and also have a mixture of archaic and modern facial and cranial features. They were found associated with tools that had elements of both old and new Stone Age

technology. The hominins' age, location and toolkit were neatly in tune with the recent out-of-Africa model and convinced the researchers that they were the “probable immediate ancestors of anatomically modern humans”. Done and dusted, you might think. But that turned out to be the high-water mark. Discoveries since then have been difficult, if not impossible, to slot into this neat little box.

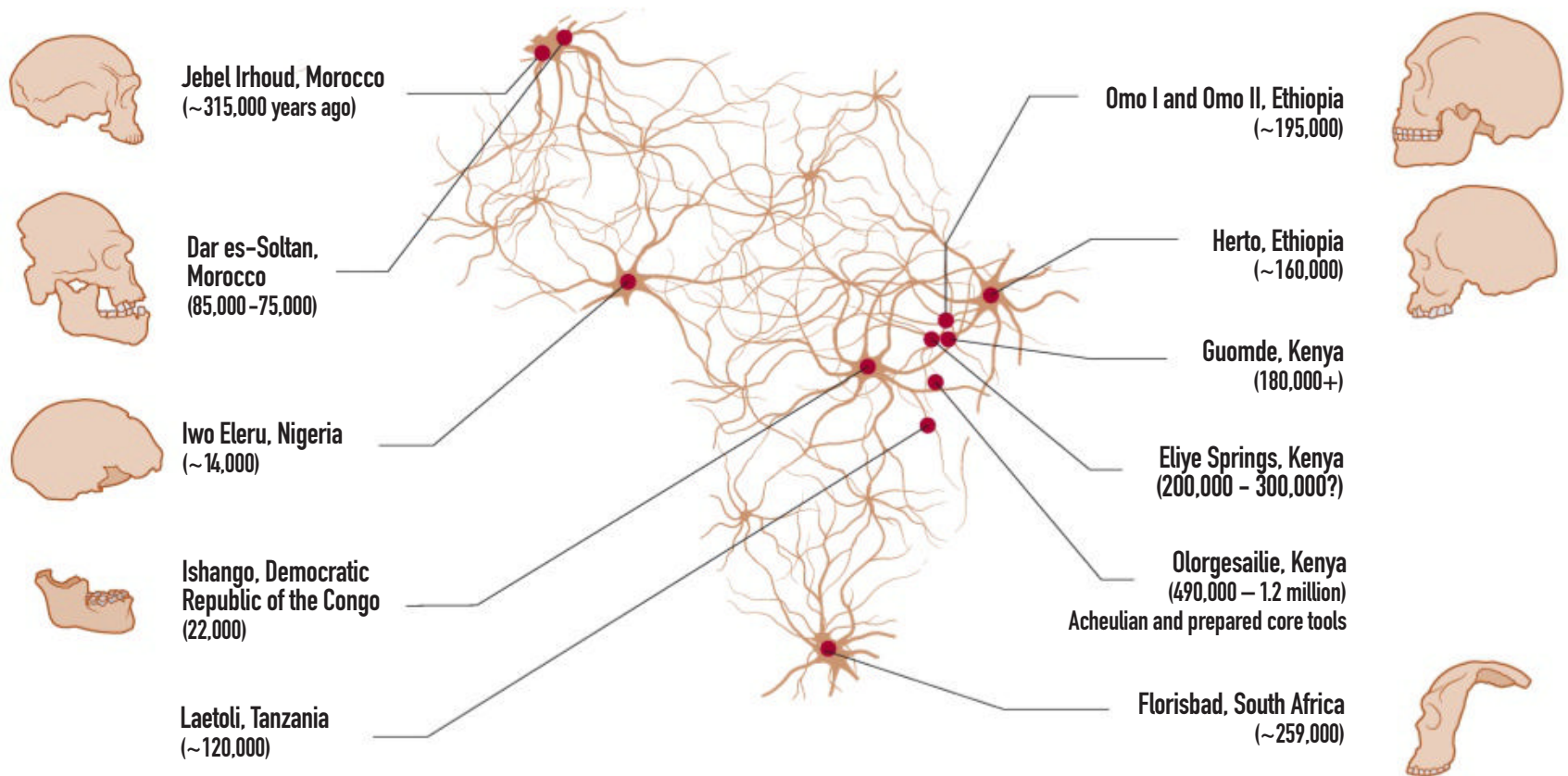
Fossils found at Jebel Irhoud in Morocco have done more than almost anything else to upend the old order. Back in 1961, a miner working in a barium mine in the foothills of the Atlas mountains made a ghoulish discovery: a near-complete human skull embedded in the sediment. Archaeologists called in to investigate noted that the skull had modern facial features – a flat and delicate face, and a prominent chin – and an archaic, elongated braincase. When it was dated to around 40,000 years old, it was classified as maybe belonging to an African Neanderthal or a relic population of another archaic hominin, and shunted to the margins of the story. But doubts about the dating persisted and, in 2004, a team led by Jean-Jacques Hublin of the Max Planck Institute for Evolutionary Anthropology in Germany reopened the site.

The researchers hoped to get a more accurate date, which they did. But they also got more fossils, including another near-complete skull. It too had a modern face and ancient braincase. And the date was astounding: 315,000 years old, plus or minus 34,000 years.

This was a serious challenge to the standard out-of-Africa idea. Anatomically, the skull is at least as modern as those found at Herto, which are considered to be right on the cusp of modern humanity. “It is a creature which is very nearly a modern human, anatomically,” says Robert Foley, a palaeoanthropologist at the University of Cambridge, UK. And yet it lived at least 130,000 years before *H. sapiens* was meant to have evolved, at a time when our direct ancestors were still banging rocks together in eastern or southern Africa. It was also on the fringes of the continent, thousands of kilometres from the supposed cradle of humanity.

ONE SPECIES, MANY ORIGINS

The idea that *Homo sapiens* evolved from a single population in eastern Africa has been undermined by discoveries of human skulls across the continent. The huge variation in their features and dates suggests that our species was born of the occasional mixing of many isolated populations



When the new Jebel Irhoud dates were revealed in 2017, they inspired a major rethink of other fossil skulls from around the same time. It turned out that these told a similar story. The Florisbad specimen from South Africa, for example, is about 260,000 years old, yet has a surprisingly modern face. Ditto some skulls from Laetoli in Tanzania and two locations in Kenya, Guomde and Eliye Springs. All possess a mosaic of modern and archaic features – but, oddly, are also very different from one another.

Another old site with a new story is Olorgesailie in Kenya. Originally excavated in the mid-1980s, it is an ancient lake bed, known for stones rather than bones, specifically an abundance of prehistoric tools. It captures a crucial changing of the guard from one tool-making culture – the Acheulian, with large, crude hand axes – to a more sophisticated one. The site is characterised by a finer and more varied toolkit based on something called the “prepared core”: a block of flint or chert worked in such a way that smaller blades and points can be struck from it with a single blow.

Making such a core requires a high level of abstract thought and planning, and so is regarded as a product of modern minds (see “The making of the modern mind”, page 31). The Acheulian toolkit, on the other

hand, definitely predates our species. It was invented by our distant ancestor *H. erectus* around 1.2 million years ago. The transition to the prepared core technology was once thought to have been relatively recent, in keeping with the human revolution model, but new dating from Olorgesailie says otherwise. The transition there happened at least 305,000 years ago, and maybe as far back as 320,000 years. Ring any bells?

Olorgesailie isn’t the only evidence of earlier-than-expected technological progress. The Jebel Irhoud fossils are also associated with prepared core tools. What’s more, Olorgesailie has yielded up tools made of a glassy volcanic rock called obsidian, which doesn’t occur locally. The nearest deposits are 25 kilometres away – possible evidence of trade networks.

The site also reveals clear signs of iron-rich rocks being processed into red and black pigments, presumably for artistic purposes, another indication of behavioural and cultural sophistication. It looks as though the transition to modern cognition happened right at the start of the *H. sapiens* journey, or maybe even before it. So much for the mainstay of the standard story, that humanity became physically modern first, and behavioural modernity evolved later. “I think the two-step model is dead,” says Foley. ➤

“*Homo sapiens* may have no one single origin – we may be a composite species”

From the stones and bones of Jebel Irhoud, Olororgesailie and elsewhere, a new and increasingly mainstream view of human origins is emerging. “African multiregionalism” doesn’t completely overturn the incumbent model. The continent is still the cradle of humanity – although, as Foley points out, “saying humans evolved in Africa doesn’t mean very much, it’s a vast area”. And humanity did disperse out of Africa around 60,000 years ago to eventually inhabit the entire world – although there may have been several forays before then that ultimately led to evolutionary dead ends. But the idea of a recent, localised origin within a discrete population has been buried. In its place is a much deeper origin story beginning at least 300,000 years ago, and perhaps as many as half a million years.



See chapter 4 for more on how humans conquered the world

“If you’re looking for a big framework in which to look at the evolution of modern humans, it is the African Middle Stone Age,” says Foley, referring to the period from about 300,000 to 100,000 years ago. At the start of this span, the whole continent of Africa – possibly even “Greater Africa”, which includes parts of the Middle East – appears to have been dotted with populations of archaic humans. These were often isolated from one another by geographical or ecological boundaries such as deserts or jungles, and mostly evolved independently, although had

sporadic contact and interbreeding, perhaps when climatic conditions changed and boundaries shifted. This fluid situation persisted for 150,000 years or more, and left behind those now-familiar mosaic skulls.

Genetic studies point in the same direction, says Carina Schlebusch at Uppsala University in Sweden. She and her colleagues analysed a collection of contemporary genomes from all over Africa attempting to home in on the origin of *H. sapiens*. “It did not point to any one particular place,” she says. “It pointed to south Africa, east Africa and west Africa. Basically, it pointed to every place where we had samples from. As I understand it, the transition from archaic to modern happened in different parts of the African continent.”

African multiregionalism represents a major shift in thinking. There was no single ancestral population, but many, spread over a huge area, which merged and split and merged again like a braided stream, evolving at different rates and in distinct directions in different places. The suite of anatomical and behavioural features that define modern humanity didn’t appear as one complete package, but gradually coalesced across vast tracts of space and time. “There was never a single centre of origin,” says Chris Stringer at the Natural History Museum in London. We are a “composite”, he says.



The next section in this chapter has more on our composite origin

The anatomical diversity of these composite humans has inevitably stoked debates about which belong to our species and which don't. Some fossils are widely accepted as being *H. sapiens*, notably Omo I and the Herto hominins (although they are substantially different from one another, and some prefer to categorise the latter as a subspecies).

The Jebel Irhoud fossils divide opinion, with some palaeoanthropologists happy to accept them into the immediate family but others not. The rejects are generally categorised, rather vaguely, as “African archaics”, which is essentially dodging the issue. Some of these might be separate species. It has been proposed, for example, that the Florisbad fossils be categorised as *Homo helmei* – however new findings appear to be undermining this idea, as we shall see.

Maybe this is all moot, anyway, hung up on an increasingly outdated concept of what constitutes a species. It is commonly taken to be a group of organisms that can interbreed. But this “biological species” concept is just one of dozens of competing definitions. Some are based on shared ancestry, others on shared behaviour, genes or anatomy.

As Stringer points out, the biological species concept doesn't hold up for many living species of mammals. Coyotes and grey wolves, for example, can interbreed to produce a third “species”, the red wolf. Why not humans too? In this emerging view, early *H. sapiens* is less a species than a clade: a group of organisms of various taxonomic groups, descended from a common ancestor and sharing many features, but also with a lot of physical variation.



The species question is explored more fully on page 47

The new model is still a work in progress: everyone accepts it is incomplete and that new discoveries could blow it out of the water. Nevertheless, it is already having some major knock-on effects for other parts of the human origin story. One of these is the search for our last direct ancestor, the species from which *H. sapiens* evolved. Under the out-of-Africa scenario, this was assumed to be the last ancestor we shared with our sister species the Neanderthals, making it relatively recent. “The numbers were vague, but people talked in terms of 150,000 to 300,000 years ago,” says Foley. The strong favourite was a species called *Homo heidelbergensis*, which lived across Africa and Europe from around 700,000 to at least 300,000 years ago. That put it roughly in the right place at the right time. And from an anatomical perspective, *H. heidelbergensis* looks like a good starting point for both species.

We now know it almost certainly wasn't. First, it has become apparent that there was no common ancestor of humans and Neanderthals. The Denisovans are even more closely related to the Neanderthals than we are. That means our last direct ancestor was the species that gave rise to us and the Neanderthal/Denisovan lineage.

More consequentially, the date of this split has been pushed way back. The latest estimate comes from a remarkable cache of fossils called the Sima hominins, the remains of at least 28 ancient hominins found in ➤

a cave called Sima de los Huesos (pit of bones) in the Atapuerca mountains of northern Spain. They are 430,000 years old and were long believed to be *H. heidelbergensis*. But in 2016 their DNA – the oldest ancient human DNA ever sequenced – revealed that they were actually Neanderthals, and pushed the split between modern humans and Neanderthals/Denisovans back to between 550,000 and 765,000 years ago. That all but rules out *H. heidelbergensis* and points the finger at an earlier species. “For about 35 years, I’ve argued that *Homo heidelbergensis* represents the most reasonable last common ancestor for Neanderthals and modern humans,” says Stringer. “I don’t believe that any more.”

So what was? The best candidate is now *Homo antecessor*, which lived about 900,000 years ago and had a very modern-looking face. In 2020, a study comparing seven proteins extracted from one of its teeth with the equivalent protein from other hominins found that *H. antecessor* was closely related to the last common ancestor of humans, Neanderthals and Denisovans. However, the researchers said they could not tell whether it actually was that ancestor. What’s more, only a few *H. antecessor* fossils have ever been found, all in Spain, also in the Atapuerca mountains. Genetics clearly indicates that modern humans evolved in Africa, not Europe, so remains would need to turn up in Africa or Greater Africa to bolster *H. antecessor*’s claim to direct ancestry.

There are three other candidates in the frame: *Homo rhodesiensis*, which may just be an African *H. heidelbergensis*, the Florisbad fossil or perhaps even *H. erectus*. But nobody can be sure. “In my view, who that ancestor was, and when and where it lived, are currently unknown,” says Stringer. For now, it is known only as Ancestor X.

Even as it becomes harder to pin down the identity of our direct ancestor, the African multiregionalism model has shifted the spotlight onto a different and, arguably, more interesting ancestor question. If, as the new hypothesis suggests, the African Middle Stone Age

was teeming with groups of more-or-less modern humans, evolving semi-independently, which of these actually gave rise to the contemporary human population? “This is the divergence we should really be thinking about in terms of the shift to modern humans,” says Foley. “And when does this occur?”

Unfortunately, at this point the trail goes quite cold. “The fossil record is very sparse,” says Foley. There are some bones, but they are scrappy and hard to weave into a big picture. The genetics is also quite fuzzy. The most recent analysis places the origin of modern humans between 260,000 and 350,000 years ago. This isn’t an error bar, but reflects the long process of patchwork evolution across swathes of Africa, says Schlebusch, who led the research.

But there may be another way to pin down the story. In 2019, Aurélien Mounier and Marta Mirazon Lahr, both of the University of Cambridge, created what they called a “virtual last common ancestor” of all living humans. By mapping the morphological variety of the skulls of ancient and contemporary humans, including Neanderthals but excluding the archaic Africans, they estimated what the skull of a supposed last common ancestor looked like in the early part of the Middle Stone Age.

They then compared their virtual skull to the five most complete skulls from that time. The fossil with the greatest similarity to the virtual ancestor was the Florisbad skull from South Africa, followed by two of the East African specimens, Eliye Springs and Omo II. Next came the Laetoli specimen. The North African skull, from Jebel Irhoud, was the least similar, closer to Neanderthals. What this suggests, they say, is that we are descended from archaic Africans in southern and eastern Africa, but not from our friends in the north. In other words, the braided stream eventually coalesced into a main channel, although still with numerous side branches.

Furthermore, fossil finds indicate that those side branches persisted until surprisingly recently. Skulls with a classic mosaic of archaic and modern features

THE MAKING OF THE MODERN MIND

Some 320,000 years ago, there was a step-change in the complexity of the tools produced by early *Homo sapiens*, which palaeoanthropologists increasingly recognise as indicating the dawn of the modern mind. The large, flat, leaf-shaped hand axes that had remained largely unchanged for 700,000 years suddenly gave way to a more sophisticated toolkit of smaller, finer points and projectiles.

One of the best places to see this revolution on the ground is the Rift valley in Kenya. The transition is particularly stark at Olorgesailie, an ancient lake bed site rich in stone tools, says Richard Potts at the Smithsonian Institution in Washington DC. “We have layer after layer of hand axes, then no more hand axes.” What you see instead is the more sophisticated tools. But, unfortunately, erosion at Olorgesailie means that the sedimentary record has a gap of around 180,000 years between these two technologies. What was happening at this crucial time to drive this epochal change in human ability?

A few years ago, Potts and his team drilled a core some 25 kilometres away in an area with a complete sedimentary record. The core is too narrow to capture tools but it tells a story of dynamic environmental upheaval about half a million years ago. “You have this complex and really interesting combination of faulting, breaking up of the landscape and climate variability,” says Potts. “All hell breaks loose.”

So far, evidence of cataclysmic change has been seen only at the drill site – a “pinprick in the Rift valley”, as Potts describes it. But he says he would expect to see it in other locations too. “We may be wrong, but at least in the place where we’re working in southern Kenya, this is what the picture shows.”

The region around Olorgesailie also records a major shift in the animals present at this time, with large-bodied grazing animals giving way to smaller and presumably harder-to-catch ones. “It’s an entirely changed ecological setting in which early hominins had to adapt,” says Potts. He thinks this wildly unpredictable environment may have been the selection pressure that drove the evolution of modern behaviour. “Flexibility becomes the new currency of evolution,” he says. We had to think smarter to survive.

have turned up in Ishango in the Democratic Republic of the Congo, at Lukenya Hill, Kenya, and at Iwo Eleru in Nigeria. They wouldn’t look out of place alongside the African archaics, but have all been dated to as little as 12,000 years ago. They may represent final holdouts of those isolated populations that were dotted across Africa at the dawn of our species. It wasn’t until about 12,000 years ago, when farming spread around the world, that these last side channels of our braided stream finally ran dry.

African multiregionalism may be in the ascendancy, but it isn’t completely triumphant. In 2019, a group of geneticists published a dissenting paper in *Nature*. They had analysed mitochondrial DNA from 1217 living people of African ancestry and concluded that they all trace their origin back to a single small population living approximately 200,000 years ago around the Makgadikgadi salt pan in northern Botswana. Now an arid semi-desert, at the time it was the largest wetland in Africa.

If true, it swings the pendulum back towards a recent origin. “This is something we have to address,” says Schlebusch. But she points to several reasons to doubt the result. For a start, mitochondrial DNA is informative about maternal lineages, but not about entire ancient populations. Just because all Africans are descended from a mitochondrial Eve who lived in Botswana 200,000 years ago doesn’t mean that they are only descended from her. They could also have had many other female ancestors whose mitochondrial lineages died out.

Indeed, a similar analysis of Y-chromosomes, passed exclusively down the paternal lineage, points to a Y-chromosome Adam in western Africa 400,000 years ago. Only by looking at full genomes can the whole picture be inferred, and these point to a pan-African origin, says Schlebusch. In addition, there is all that evidence from tools and fossils. “Single-place origin is not the best model to describe what actually happened in Africa,” she says. “It’s more like a river delta splitting and merging through time.” ■

OUR RAINBOW ORIGINS

How can *Homo sapiens* have originated as many distinct populations that were nevertheless all one species? In truth, the story seems even stranger than that: it looks as if this diversity persisted in Africa for most of our species' existence.

IMAGINE visiting a tourist attraction in any major world city. There are people from all over – a Nigerian family, a Chinese couple, a German school party, and more. They all look very different from one another, which isn't surprising given that their ancestors have lived in far-flung parts of the world for generations. Yet, everyone alive today can trace their origins back to Africa, so there must have been a time when such physical differences didn't exist, right? Actually, no.

In fact, if you were to travel back to the very beginnings of our species and select a random group of humans, they would look unlike anyone living today in Africa or elsewhere. What's more, they would show extraordinary physical variation – greatly exceeding that in modern human populations. Far from becoming more diverse as we have adapted to life in different parts of the planet, *Homo sapiens* is more homogeneous today than our ancestors were. This is a real puzzle. It simply doesn't fit with the long-held idea that we arose from a single population in a corner of eastern Africa. But it does fit with the emerging new idea of our species' origins.

Humans alive today have a characteristic skull shape, including a rounded braincase, a smooth, high forehead, a small face and a prominent chin. However, these features don't appear all together in any early member of our species. Instead, we see a wide variety of skulls that exhibit different mixes of modern features alongside archaic ones, such as large, robust faces, pronounced brow ridges and elongated braincases.



The “modern” jawline of this 315,000-year-old fossil from Jebel Irhoud in Morocco poses a puzzle for palaeoanthropologists

Take the Jebel Irhoud fossils from Morocco. In 2017, these were dated at 315,000 years old, making them up to 150,000 years older than any other known member of our species. Yet the skull had a mixture of features. “These early individuals had modern faces and modern teeth, but elongated braincases. This suggests that features of brain shape, and perhaps even brain function, emerged within our species,” says Philipp Gunz of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, who analysed the fossils.

Meanwhile, other far younger *H. sapiens* specimens appear much more ancient. These include fossils found at Ishango in the Democratic Republic of the Congo, which, although dated to just 22,000 years ago, have decidedly robust, archaic features. Then there’s a skull with an odd, elongated braincase found in southern Nigeria. It is around 12,000 years old, yet looks more like fossils dating from 100,000 to 300,000 years ago than people living today. Some of these fossils had even previously been discounted as being early examples of *H. sapiens*.

Compounding these biological anomalies are archaeological ones. In 2014, Eleanor Scerri, now at the Max Planck Institute for the Science of Human History in Jena, Germany, uncovered Middle Stone Age tools in the far west of Africa dating to the same late time period, around 12,000 years ago. When most other African populations had progressed to making diminutive stone tools known as microliths for tasks as diverse as tattooing and producing multi-component weapons, this group had retained the technology

associated with the earliest *H. sapiens*.

There are two possible explanations. Perhaps other hominin species were living in Africa alongside us for far longer than anyone imagined. Alternatively, these strange-looking beings were all humans. In other words, a diverse array of *H. sapiens* populations, displaying a mosaic of archaic and modern features, lived over an extensive geographic area from what is now Morocco to South Africa between about 300,000 and 12,000 years ago. This new perspective has been dubbed African multiregionalism.

How could such widely dispersed and physically diverse populations all belong to a single species? One way to conceive of this is to imagine the human lineage as a river. Although there is only one river/species, as time passes, different channels branch off and rejoin it. Just as the river’s braids are separated by islands that form and are submerged, so environmental barriers kept our ancestors apart, and adapting to different conditions. This fits with emerging evidence of asynchronous changes in climate across different regions of Africa as our species began to appear. For example, the Sahara repeatedly greened for short periods every 100,000 years or so, while equatorial Africa underwent extended periods of drought. These and other similar processes across the continent would have created fluctuating barriers, shifting human populations around and modulating their degrees of isolation. Moreover, studies of other African mammals indicate that such conditions explain much of the physical diversity found within a species.

In the African multiregionalism model, east Africa ➤

Many desert and forest areas of Africa crucial to our story remain unexplored by fossil hunters

is still important in human evolution. However, the origins story featuring a single, small population in the savannah is out. Instead, a messy beginning involving many populations, regions and environments is in. Although this scenario is more complex, it reconciles the genetic, fossil and archaeological evidence.

African multiregionalism also explains the early, pan-African emergence of Middle Stone Age technology as an outcome of becoming human. For about 1 million years, hominins shaped rocks into handheld axes and other large cutting tools, such as picks and cleavers. Then, there was a shift towards far more sophisticated techniques. This technology, known as the Middle Stone Age, focused on the chipped stone flakes that came off rocks, rather than the rocks themselves. These flakes were shaped and mounted onto wooden shafts in complex ways, often using glues and bindings manufactured according to specific recipes. The ability to create and combine items that don't occur together in nature in anticipation of a range of diverse tasks has long been seen as a reflection of advanced cognition. It is considered a hallmark of our species. But here is the thing: abundant evidence makes it increasingly clear that the Middle Stone Age didn't emerge in one location at the purported dawn of humanity. Instead, there was a wholesale, continent-wide shift to this new technology around 300,000 years ago.

Indeed, the oldest hints of this sophisticated technology may date to around half a million years ago, which reinforces the idea that our species might have originated even as early as that. Subsequently, populations repeatedly came into contact with one another over timescales of around 100,000 years, exchanging genes and ideas. In this way, the process of morphological and behavioural modernisation eventually took place across the entire African continent.



ELEANOR SCERRI

The archaeological record also reveals how these modern brains began to create a variety of technologies in different regions of Africa. An incredible flowering of material culture – featuring some of the earliest examples of art and ornamentation – occurred at the extreme ends of Africa between 130,000 and 60,000 years ago, when the central regions separating them were much less habitable. The objects from southern and northern Africa show early signs of sophistication and are comparable in their complexity. However, they are so utterly different from each other and anything seen elsewhere, they suggest that the populations who made them had been isolated for a long time. Zooming in on north Africa, Scerri found that groups of people living in regions separated by ecological barriers such as deserts or rivers showed variations in their material culture. In other words, even within this smaller region, they appear to have remained relatively isolated from one another.

Vast swathes of Africa are yet to be explored for clues about our beginnings and could yield the crucial pieces of the human origins puzzle. Discoveries documenting early human habitation in Asia's rainforests indicate that we ignore environments such as forests at our peril. Our species might have exchanged genes with late surviving hominins hiding out in forests. Adaptations to different habitats may also have kept human populations apart in Africa. Such scenarios would help explain why early humans exhibit such a profusion of forms. We see this mix of ancient and modern features in fossils and in objects people created right up until 12,000 years ago. Then it vanishes. What happened?

We know that 12,000 years ago marks the beginning of a revolution for humanity. This is when Earth's climate entered a warm and unusually stable period known as the Holocene, which persists to this day. It seems likely that people have always tried to control

and alter their environment, but with climatic stability such experiments were finally able to take off. Farming was born. And this had big implications for human evolution.

For a start, it shaped our genome. "The intense genetic selection precipitated by agriculture is like nothing seen before," says Mark Thomas at University College London. "Lactase persistence – the ability to digest the main sugar in milk as adults – evolved rapidly during this time, giving a huge advantage to dairying populations over hunter-gatherers." Farmers are also much better equipped than hunter-gatherers to weather a range of environmental threats through agriculture itself. As a result of these genetic and cultural adaptations, farming populations grew and migrated into new areas so that over the next few thousand years, most people were living this way. The homogenising effect on humanity was so pronounced that Marta Mirazon Lahr at the University of Cambridge has dubbed it the "Holocene filter".

Yet the truly astonishing revelation is that we were so diverse in the first place. As this new narrative is fleshed out, there are bound to be more surprises. Who knows what treasures lie in Africa's forests and in its central and western regions? Studies so far have only scratched the surface. The secrets locked up in DNA could be just as revelatory. No early member of our species has yet had its DNA sequenced because heat and humidity, common in Africa, degrade ancient DNA. But with improvements in genetic analysis it is surely only a matter of time. Somewhere, perhaps in a deep, cool cave, lies a fossil containing the blueprint of an ancient *H. sapiens*. Decoding it will open a whole new chapter in the rapidly evolving story of our origins. ■



Turn to chapter 3 for more on ancient DNA



CHAPTER 3



WHAT ANCIENT DNA TELLS US

Little more than a decade ago, the first ancient genome was sequenced. This huge technical achievement opened a whole new window on our past, and promised intimate insights about our interactions with now-extinct members of our family tree.

Since then, palaeogeneticists have been probing more ancient fossils to find out how they fit in. They have also devised ways to uncover our pre-human ancestry by peering into the genomes of living people from around the world – with results that upend preconceptions about our heritage still further.

THE GHOSTS WITHIN US

The genetics revolution has transformed our ability to delve into our ancestry. It also has profound implications for how we see ourselves. Where early genetic studies seemed to indicate that our ancestors never interbred with other hominins, we now know that many of us possess genes from several other species. What's more, some of the fossils in our DNA are "ghosts", mystery species unknown from bones, tools or other artefacts that may never be identified.

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SCIENCE PICTURE CO/ALAMY

THE idea that each of our cells might contain fragments of genetic code from extinct hominins has been around for decades. The problem was identifying what those genetic sequences might look like. To do that, you would need to sequence ancient DNA and then compare it with the modern equivalent sequences. But DNA degrades with time. It would take special fossils and special skills to extract it from very old bones, particularly if they had spent thousands of years buried in a hot climate, as our African ancestors have.

Geneticists began to show an interest in archaeological remains in the late 1990s. With the technology available then, they managed to sequence a small chunk of mitochondrial DNA (mtDNA) – the genetic material in the cell's powerhouse – from an ancient Neanderthal bone. The sequence was clearly distinct from that of *Homo sapiens*, seeming to suggest that Neanderthals, who lived in Eurasia from around 200,000 years ago to 40,000 years ago, had gone extinct without interbreeding with our species.

But mtDNA is unusual. Unlike the nuclear DNA responsible for the bulk of human genetics, it passes intact from a mother to her children and doesn't mix with the father's genes. That makes it the worst DNA to reveal evidence of interbreeding. Geneticists knew that to resolve the question of whether human ancestors got cosy with Neanderthals they would need to probe the secrets of ancient nuclear DNA. It would be a decade before the technology had advanced enough to do that.

In 2008, Svante Pääbo pulled off that master stroke. He and his team at the Max Planck Institute for ➤



“Current estimates are that many people’s genomes are 2 to 4 per cent Neanderthal”

Evolutionary Anthropology in Leipzig, Germany, became the first people to sequence nuclear DNA from an extinct human ancestor – a 40,000-year-old Neanderthal. Even when it is present in a fossil, ancient DNA is usually swamped by genetic material from bacteria and fungi that have infiltrated the sample while it lay in the ground. Working in a clean room to avoid contamination from their own DNA, Pääbo and his team used enzymes to remove these unwanted sequences and managed to isolate tiny fragments of Neanderthal nuclear DNA. Then they replicated these and used a computer to pinpoint overlapping segments so that they could stitch the genome back together.

That was tough enough, but extracting information about the past from ancient DNA isn’t straightforward either. To find out whether Neanderthals interbred with early modern humans, the scientists compared the ancient genome with those of people alive today. Because of our common ancestry, we share the vast majority of our genes with these groups, but the differences are telling. Pääbo’s team focused on “single nucleotide polymorphisms”, or SNPs (pronounced “snips”), which are sites on the genome that vary from person to person by a single DNA “letter” (see “How DNA reveals our prehistory” on page 43).

These comparative studies revealed that early humans had indeed mated with Neanderthals, and not just once. The researchers found that Europeans and Asians share a similar number of SNPs with Neanderthals, but Africans share very few. In other words, Neanderthals are genetically closer to people

with more recent ancestry from outside Africa than to those of modern African heritage. Current estimates are that the genomes of everyone except Africans are between 2 and 4 per cent Neanderthal.

Here were two clearly distinct species, which we now know to be separated by up to 765,000 years of evolution, yet the remnants of their sexual proclivities are captured in the DNA of the majority of people alive today. What’s more, it soon emerged that our ancestors didn’t only make out with Neanderthals.

Just as Pääbo was finishing sequencing the Neanderthal genome, a parcel landed on his desk. It contained a tiny fragment of a finger bone from the Altai mountains in Siberia. The piece was 30,000 to 50,000 years old and was thought to be from another Neanderthal. His team was in for a big surprise. Their DNA analysis revealed an entirely new group of archaic humans, now dubbed the Denisovans, which seemed to have split from a common ancestor with Neanderthals roughly 430,000 years ago. Once again, comparisons with modern human genomes showed that our species interbred with them. Almost all non-Africans have Denisovan SNPs, but these are most prevalent in Melanesians, whose DNA is between 4 and 6 per cent Denisovan. Genetic studies also show that Denisovans ranged from what is now Siberia to South-East Asia. As with the Neanderthals, interbreeding with humans must have happened in Eurasia.



Find out more about what we know of the Neanderthals and Denisovans in chapter 5

Tantalisingly, breeding with Neanderthals and Denisovans may not be the end of our ancestors' promiscuity. Research published in 2018 found that a quarter of the chunks of ancient DNA in living humans didn't match either Neanderthal or Denisovan DNA. So we may have also had children with other, unidentified hominins. Other geneticists have come to a similar conclusion. They call these elusive ancestors "ghosts" because we have no physical record of them – no bones, no tools, no archaeological remains whatsoever – yet they live on within our DNA.

Denisovans are nearly ghosts: we have that one finger bone, a few molars and a jawbone as a physical testament to their existence, but no more. Then in 2016, the first true ghost emerged from the genomes of 44 individuals who lived in the Middle East between 14,000 and 3400 years ago. Their DNA held genetic markers indicative of a distinct group of ancient *H. sapiens* based in the region more than 45,000 years ago. The members of this population are now known as Basal Eurasians, and they present a conundrum. Their DNA, which is still found in modern Europeans, shows none of the telltale signs of interbreeding with Neanderthals. This came as a surprise because ancestral humans mated with Neanderthals very soon after leaving Africa 60,000 years ago in the migration that was to give rise to all people of non-African heritage alive today.

The most-likely explanation is that soon after that migration, a group of humans became isolated while the rest bumped into and mated with Neanderthals. "If you like, it's a third branch," says Chris Stringer of the Natural History Museum in London – a branch that is

distinct from the humans who had stayed in Africa and the ones who were gradually spreading out across Eurasia, Australia and eventually into the Americas. Because there are no known fossils belonging to Basal Eurasians, it is impossible – for now – to say why they were isolated. Perhaps it was just down to where they settled, far from other groups. Or maybe they developed cultural differences. Either way, these ghosts didn't mix with the rest of humanity for millennia, long enough to evolve distinct genetic markers.



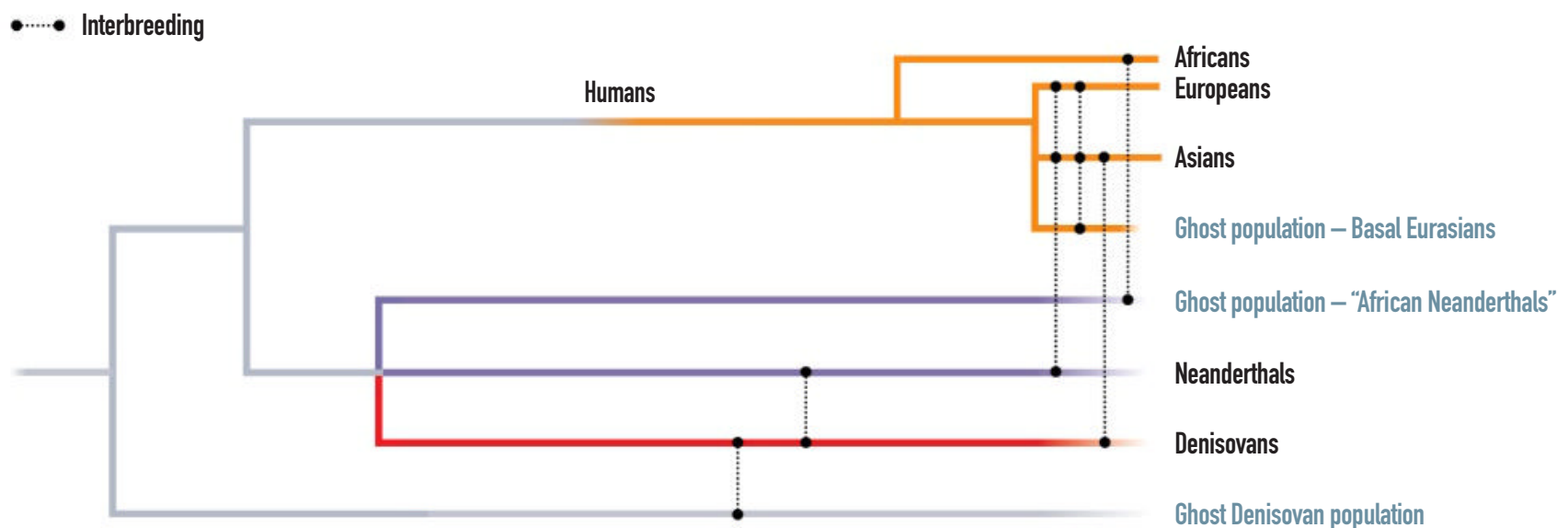
See chapter 4 for more on how humanity spread globally

The Basal Eurasian research showed that rich insights into human history can be gleaned from DNA alone. But, like the Neanderthal and Denisovan studies, it relied on obtaining DNA from fossils, something that remains a huge challenge. However, in the mid-2000s, geneticists were already discussing another approach. They suggested that it might be possible to spot signs of extinct populations in the DNA of modern humans, simply by using clever statistics.

The broad idea is that all DNA is subject to random mutations that accumulate over millennia and are passed down from generation to generation. By looking at mutation patterns in modern populations, it is possible to spot segments that don't match the usual *H. sapiens* pattern. These are presumed to come from populations that evolved separately from our own species for thousands of years before mating ➤

MYSTERY ANCESTORS

Genetic analysis has revealed that our family tree contains at least three ghosts: species or populations for which we have no evidence except for their DNA



with humans. Statistical modelling can then produce estimates of when the two groups mated and how different the other population was from our ancestors.

The past few years have seen several attempts to refine these methods and apply them to Africa – the birthplace of our species and the setting for a slice of our history that we know very little about. It was once assumed that interbreeding between early humans and other hominins happened exclusively outside Africa. Although Pääbo and others have found small amounts of Neanderthal DNA in the genomes of people living in Africa, Neanderthals never seem to have inhabited that continent, so the DNA almost certainly arrived as a result of early humans migrating back to Africa from Eurasia. However, more recent analyses suggest that human ancestors did interbreed with other hominins on the continent. In fact, the genomes of some people in Africa are 19 per cent “ancient”, which far exceeds any Neanderthal or Denisovan contribution to Eurasian genomes.

Josh Akey at Princeton University, Sarah Tishkoff at the University of Pennsylvania and others have spent years sequencing and analysing the genomes of modern Africans who belong to groups with deep ancestral roots, including the Baka hunter-gatherers from Cameroon, and the Hadza and Sandawe from Tanzania. Within these genomes, they have found stretches of DNA that appear to come from another hominin species. Because this DNA is found only in the descendants of African people – not in any Eurasians – the ghost species must have interbred with *H. sapiens* after the out-of-Africa migration 60,000 years ago. In

fact, by the team’s calculations, this probably happened within the past 30,000 years. If true, this is huge. It means that until very recently, there was at least one other species of hominin living alongside us in Africa.

Then, in 2018, Arun Durvasula at the University of California, Los Angeles, scanned the whole genomes of people from four sub-Saharan populations and found signals of an earlier coupling with another ghost species. It seems to have split from our lineage about 625,000 years ago, and then interbred with humans up to 124,000 years ago. This was before the mass exodus out of Africa, which would explain why European genomes carry the same ghost DNA. In 2020, analysis of four skeletons from Cameroon – two of which were 8000 years old and the others 3000 years old – saw hints of yet more ghost DNA from an encounter that happened around 250,000 years ago.

Who might these mystery relatives be? Akey suspects he and Tishkoff have found evidence of “African Neanderthals”. The African ghosts appear as evolutionarily distinct from modern humans as Neanderthals and Denisovans are. “What this means is that they probably came from the same African population that Neanderthals trace their ancestry to,” he says. “So the idea is that 700,000 years ago, there’s a population in Africa that splits off from the modern human lineage, goes out of Africa and becomes what we recognise as Neanderthals. At the same time, there’s another split in Africa that becomes sort of like an African Neanderthal.” Of course, that still leaves the mystery of who these “African Neanderthals” were.

One clue could come from a fossil from Nigeria ➤



HOW DNA REVEALS OUR PREHISTORY

Genetics is now at the leading edge of human evolution research but extracting information about the past from DNA isn't straightforward. The techniques rely on arcane statistics and computational biology. However, the basic principles are easy to grasp.

One key thing that DNA can tell us is how long ago two lineages diverged, for example, when the ancestors of Neanderthals and *Homo sapiens* split. These analyses are based on mutations, says Carina Schlebusch at the University of Uppsala in Sweden. The simplest method uses mitochondrial DNA, a self-contained mini genome found inside cells' mitochondria, which produce energy. This is passed on directly from mothers to their offspring. "We sequence different mitochondrial genomes and then compare and count the different mutations between them," she says. "Then, using the rate at which mutations accumulate, we date how long ago the mitochondria diverged from each other."

Extracting information from DNA on the Y-chromosome – which is passed from fathers to sons – is also quite straightforward because, like mitochondrial DNA, it is inherited intact. Other chromosomes, however, undergo a process called recombination during the formation of sperm and eggs, in which pieces of DNA are shuffled around. This makes them trickier to analyse.

But mitochondrial and Y-chromosome DNA don't tell the whole story, so methods have been developed to estimate divergence times using other chromosomes. There are two approaches. "One is to take recombination into account, using recombination maps to know where the hotspots are," says Schlebusch. "Another is to ignore recombination by using small pieces of DNA randomly sampled across all of the chromosomes." If these pieces are tiny enough, researchers assume they have been passed down the generations pretty much intact.

As well as revealing branching in our family tree, DNA can also indicate when separate populations – or species – interbred. "When populations split from each other back in time, they evolve independently and accumulate patterns of mutations that are distinct," says Arun Durvasula at the University of California, Los Angeles. Then, when interbreeding happens, the resulting genomes will be a mixture of these distinct patterns. "We can look for these patterns across the thousands of genomes we have sequenced from individuals around the world," he says.

The time of these interbreeding events can be estimated, too. When interbreeding happens, large stretches of DNA come from one population or the other. However, these become smaller and smaller over generations, because of recombination. This reduction in size happens at a certain rate, which is what allows geneticists to work out when interbreeding occurred.

called the Iwo Eleru skull. At around 13,000 years old, this individual was alive just a millennium or so before some humans first started farming, yet it has a strange mix of modern and primitive features. Recently, a fresh analysis of the skull has confirmed that it is very odd for its age. “It actually resembles early *sapiens* fossils rather than late ones, and it certainly doesn’t look like any recent Africans,” says Stringer, who first studied the skull for his PhD back in the 1970s. “We suggested this could be an example of an African whose population had received this archaic introgression.” In other words, it might be a human whose ancestors mated with an African ghost.

As with the other ghosts, it is possible we will never discover fossils of an African Neanderthal. However, given that no ancient African hominin has yet had its genome sequenced, there is a chance that physical remains of these ghosts have already been unearthed. One candidate is *Homo naledi*, the primitive-looking hominin that was discovered in South Africa in 2013. The fossils are around 250,000 years old, but no one knows how long the species survived.



See the profile of Lee Berger on page 18 for more on *Homo naledi*

If pressed, however, Stringer would put his money on another suspect. “My bet is that *Homo heidelbergensis* is the introgressor,” he says. Discovered in Germany in 1908, this species is thought to have evolved around 700,000 years ago and was the first hominin to live in

colder climates. However, it seems to have been widely distributed from northern Europe to southern Africa. What’s more, recent evidence suggests that *H. heidelbergensis* was still around less than 300,000 years ago, when humans had already appeared.

Another possibility is *Homo antecessor*, which is now thought to be our direct ancestor. It is known to have lived in what is now northern Spain between 1.2 million and 800,000 years ago – although we still don’t have evidence that it inhabited Africa. Alternatively, the ghosts may have been subpopulations of *H. sapiens* that, like the Basal Eurasians, were isolated from other populations for long enough that their members’ DNA acquired different markers. “It could be the case that 100,000 years ago or more, there are different populations of anatomically modern humans in different parts of Africa,” says Tishkoff. “And maybe at some point they mix with each other and maybe some populations died out.”



See page 32 for more on our rainbow origins

Tishkoff thinks it would be surprising if our ancestors didn’t mate with other ancient hominins in Africa. However, she cautions that the evidence for African ghosts is still tentative: because we know so little about the population history of Africa, she and her colleagues had to make many assumptions to interpret their data. Hybridisation is really difficult to prove, she says. The clincher will come when someone is able to sequence DNA extracted from an African fossil and compare it



People in Papua
New Guinea have some
Denisovan DNA

with the fragments of ghost DNA found in modern Africans. That is a challenge but, given the advances in ancient DNA sequencing in the past decade, it is probably only a matter of time before someone meets it. Meanwhile, there seems little doubt that new studies will turn up other ghost ancestors in our DNA.

“Genetics in general is changing how we understand our species,” says Tomas Marques-Bonet at Pompeu Fabra University in Spain. “To me, everything starts with Denisovans: the first time we lifted DNA from a finger and found neither human nor Neanderthal – something for which we have no face and very little other information – that was the first time genetics illuminated something that had totally escaped palaeontology.”

It now transpires that Denisovans had their own ghosts. People living in Oceania and East and South-East Asia today have inherited about 5 per cent of their DNA from Denisovans. By taking a closer look at these genetic sequences, Akey’s team found that they don’t all relate to the original finger-bone genome in the same way. In fact, the group found signs of two evolutionarily distinct Denisovan populations. “That was really unexpected,” he says. “There’s actually another, ghost, Denisovan lineage.”

A recent study has fleshed out this story. In 2018, Sharon Browning of the University of Washington in Seattle and her colleagues trawled for segments of ancient DNA in the genomes of 5600 living humans from Europe, Asia, America and Oceania. They found that the Denisovan DNA in some East Asians – especially Han Chinese, Chinese Dai and Japanese people – is different from that in Australasians, which

is more of a match for the DNA sequenced by Pääbo’s team. This supports Akey’s finding. There seem to have been at least two distinct populations of Denisovans living in Asia, probably somewhat geographically isolated. One of these bred with modern humans in East Asia, and the other further south-east in Indonesia or Australasia. In 2019, results from another genetic analysis suggested that people in Papua New Guinea might have bred with Denisovans as recently as 15,000 years ago.

What all these studies highlight is that it was the rule, rather than the exception, for hominin populations to split for thousands or even hundreds of thousands of years and then meet again and mate. Neat, bifurcating evolutionary trees must be abandoned. “Take a pen on a piece of paper and start making squiggly lines,” says Akey. “That’s human history.” Some researchers go even further, suggesting that the discovery of so much interbreeding between *H. sapiens* and other hominins might force us to reconsider where the boundaries between ours and other species lie.



Read more on “What counts as human?”
later in this chapter

Ghosts and nearly-ghosts are making the ancient world a much less lonely place. “If we look around the world today, we are really the only hominin game in town,” says Akey. “People assume that’s the way it must have always been. In fact, the world was a much more interesting place not that long ago.” ■

OUR ANCIENT INHERITANCE

Dozens of genes found in humans today have been traced to Neanderthals and Denisovans, a legacy of interbreeding between our direct ancestors and these now-extinct lineages. Some of this “undead” DNA has proved very useful in making us what we are.

THE first *Homo sapiens* to arrive in Europe and Asia would have encountered new parasites and pathogens, leaving them at risk from deadly diseases. Bumping into Neanderthals and Denisovans may have had very real advantages to these early explorers. One indication of this is that modern Eurasians owe a significant portion of their immune system genes to these two ancient humans, genes adapted over millennia to help in the fight against local infections.

Seventy per cent of people with European ancestry also carry a segment of Neanderthal DNA on chromosome 9 linked with pale skin. Dark skin protects people from the harmful effects of UV radiation, but makes it harder to generate vitamin D at higher latitudes. Pale skin could have helped members of our species survive on less sunlight as they migrated north. Early human populations that travelled furthest north may have benefited from Denisovan DNA too. One particular sequence, found on chromosome 1, helps in the formation of brown fat cells, which generate heat when stimulated by cold temperatures. It is present in nearly all indigenous Inuit Greenlanders.

Perhaps the most dramatic evidence of modern

benefits from ancient DNA is seen in Tibetans. Emilia Huerta-Sánchez at the University of California in Merced and her colleagues found that about 80 per cent of Tibetans carry a particular piece of Denisovan DNA. This stretch overlaps with the *EPAS1* gene, the Denisovan version of which seems to help people survive the low-oxygen conditions at high elevations. It's possible that Denisovans were adapted to life at altitude and passed the trait to humans. A 160,000-year-old Denisovan jawbone found in Tibet lends weight to this idea.

Not all the DNA inherited from our extinct ancestors is so useful. Neanderthal DNA spanning a group of genes called TLRs may increase susceptibility to hay fever and common allergies – to cats and dust mites, for instance. And other segments of Neanderthal DNA slightly increase the risk of depression, heart attack and type-2 diabetes. Nevertheless, it is likely that such genes also bring advantages because if their carriers were at a competitive disadvantage, natural selection would have removed them from our gene pool over time.

This can be seen with a gene called *PGR*, which plays a part in pregnancy. In 2018, researchers discovered that a version of this gene that contains Neanderthal DNA increases the chance of premature birth. Yet, in some populations, 20 per cent of people carry this version. This puzzled Hugo Zeberg at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, but he has found an explanation. His study, published in 2020, revealed that women with the Neanderthal version of the gene were less likely to have experienced miscarriage or unexpected bleeding during early pregnancy. Zeberg speculates that some of these premature births would have been miscarried if the woman lacked the Neanderthal allele. “It might preserve pregnancies that would otherwise be lost at an early stage,” he says. Even though the Neanderthal gene is also linked with premature births, if it increases fertility overall, that would explain why so many women still carry it. ■



The “Denny” fossils revealed an unexpected twist in the human story

WHAT COUNTS AS HUMAN?

Recent revelations about interbreeding between ancestral *Homo sapiens* and various other hominins have left many of us wondering: who are “we”, who are “they” and are we actually all one and the same? How we define a species has become a question at the very heart of human identity.

THE idea that hybrids are in some way unnatural and of lower intrinsic value is surprisingly common. You see it most clearly in decisions about conservation where hybrids are often considered less worth of protection. In fact, this view is outdated. It arises from the assumption that species, at least in the animal kingdom, are distinct once formed. In the past few decades, however, biologists have been astonished to discover that the opposite is true: hybridisation between animal species is common. Genetic analysis reveals, for example, that the critically endangered red wolf is a cross between the grey wolf and coyote. Likewise, one of the world’s rarest fish, the Devil’s Hole pupfish, seems to be a hybrid.

Now we know that the hybrid issue extends all the way to our doorstep. In August 2018, researchers managed to sequence the DNA from a bone fragment found in Denisova cave in southern Siberia, belonging to an individual who had died 90,000 years ago. A previous study of proteins preserved inside it had shown that the fossil belonged to a hominin, and the structure of the bone indicated it was about 13 years of age at the time of death.

But results from the genetic analysis were astounding. The genome revealed that this individual, nicknamed “Denny”, was female – and she was the daughter of parents from two different hominin groups. DNA comes in paired strands called ➤

chromosomes, one from each parent. In Denny's case, each pair had one Neanderthal and one Denisovan chromosome, with very little mixing, making Denny the only first-generation hybrid hominin ever found. Her mitochondrial DNA, which is inherited only from mothers, is Neanderthal. So we also know that she had a Neanderthal mother and a Denisovan father.

Reporting this, one of the most astonishing science news stories of the year, the cover of *Nature* read: "Ancient Human Hybrid". From a lay viewpoint that may seem uncontroversial, but it is more complicated than that. "The research paper is so careful not to use the word hybrid," says John Hawks at the University of Wisconsin-Madison. "And yet it is there on the cover of the journal: hybrid found!" He points out that the genetic difference between Denny's father and mother may reflect a history of divergence that lasted no longer than that seen between some human populations that happily interbreed today. "But it would be wrong to look at a living person and say: hybrid," he says. "We don't use that term for a reason."

Yet perhaps we should consider *H. sapiens* as a hybrid, given the discovery in recent years that there is Neanderthal or Denisovan DNA in the cells of many living humans. Clearly, after tens of thousands of years of independent evolution, members of the three populations – Denisovans, Neanderthals and humans – met and interbred. If these other hominins are distinct species, then that would make many of us "unnatural" or "valueless" hybrids, which is absurd.

Nevertheless, the fact that such a conclusion could be reached might help explain why some experts in human evolution are cautious about using the term "species". These include geneticist Johannes Krause at the University of Tübingen, Germany, who with his colleagues first identified the Denisovans. They didn't – and still don't – claim Denisovans to be a distinct species. They prefer the less loaded term "population". In the ongoing debate about how to classify these groups of Stone Age peoples, others have gone as far as to argue that we should consider *H. sapiens*,

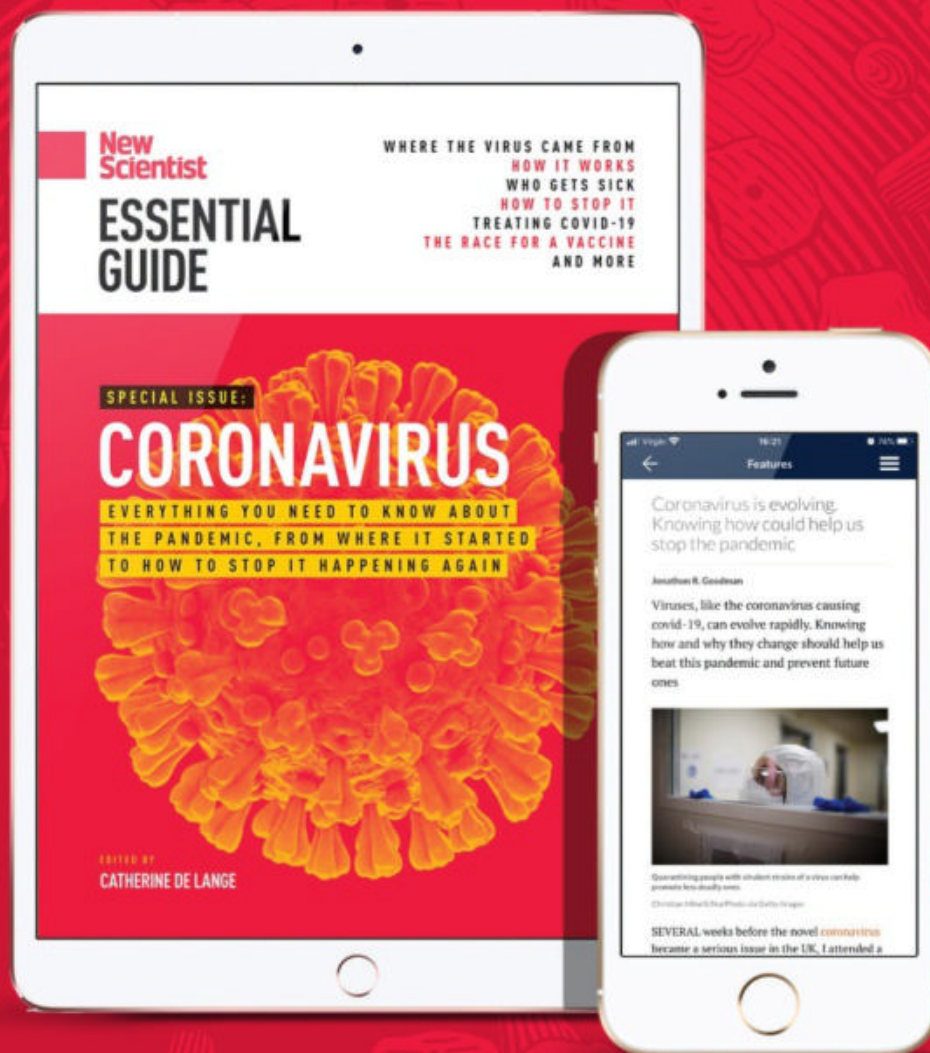
Neanderthals and Denisovans as all one species.

But there is another way of looking at this. The popular conception of "species" holds that individuals belonging to different species – like *H. sapiens* and *H. neanderthalensis* – aren't meant to be able to produce viable offspring. This, however, is just one of at least 34 competing definitions of "species". This partly reflects the distinct ways that researchers in different subsets of biology see the living world. Ecologists, for example, focus on environment, resources and adaptation, whereas palaeontologists are more interested in the shape of the fossils they study. It also reflects developments in science, with advances in genetics now making it possible to decode the DNA of individual organisms and reconstruct family trees. The revolution in palaeogenetics is the latest innovation forcing us to rethink the definition of species.

One solution to the problem might be to remove the word "species" from the scientific lexicon altogether. In 2018, Brent Mishler at the University of California, Berkeley, and John Wilkins at the University of Melbourne, Australia, set out this argument. They suggested that we should focus on another division of life, the "clade", a group sharing a common ancestor and so comprising a separate twig on the tree of life. Then we could classify organisms as the Smallest Named and Registered Clade, or SNaRC, rather than as species. So, for example, Neanderthals, Denisovans and living humans would be three distinct SNaRCs. There is nothing intrinsically special about SNaRCs, according to Mishler: they might interbreed or not, and the groups that fit the classification would vary across the tree of life, forcing us to accept that there is no common currency.

Given how much wrangling there has been over the definition of "species" over the centuries, it is perhaps not surprising that this new idea has critics too. Nevertheless, it is likely that the debate about what counts as a human will only increase as we uncover ever more evidence of intermingling within the human genome. ■

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CHAPTER 4

GOING GLOBAL



One of the defining features of *Homo sapiens* is that we are a global species, spread into most corners of Earth. But how did that come to be?

In keeping with the rest of the human story, our ideas are evolving. But here is what we currently know about how we left Africa and conquered the world.

WHEN DID HUMANS LEAVE AFRICA?

When fossilised hominin bones were first found in China in the early 20th century, they were taken as evidence that the origins of *Homo sapiens* lay in Asia. We now know better, but we are also coming to realise that Asia was awash with a variety of different hominin species long before we arrived.

How these awkward finds fit into our family tree isn't yet known, but anthropologists have some intriguing ideas. What's more, they are unearthing increasing numbers of ancient human fossils that don't fit with our ideas about when members of our species struck out from their ancestral home.

IN 1923, archaeologists began to unearth fossilised human remains some 50 kilometres outside Beijing. Alongside broad-nosed individuals with thick brows were burnt animal bones, suggesting a species that could control fire. Only four other ancestral human species had been discovered at that time, including Neanderthals in Germany and *Australopithecus africanus*. At around 700,000 years old, the Chinese fossils were older than any of them.

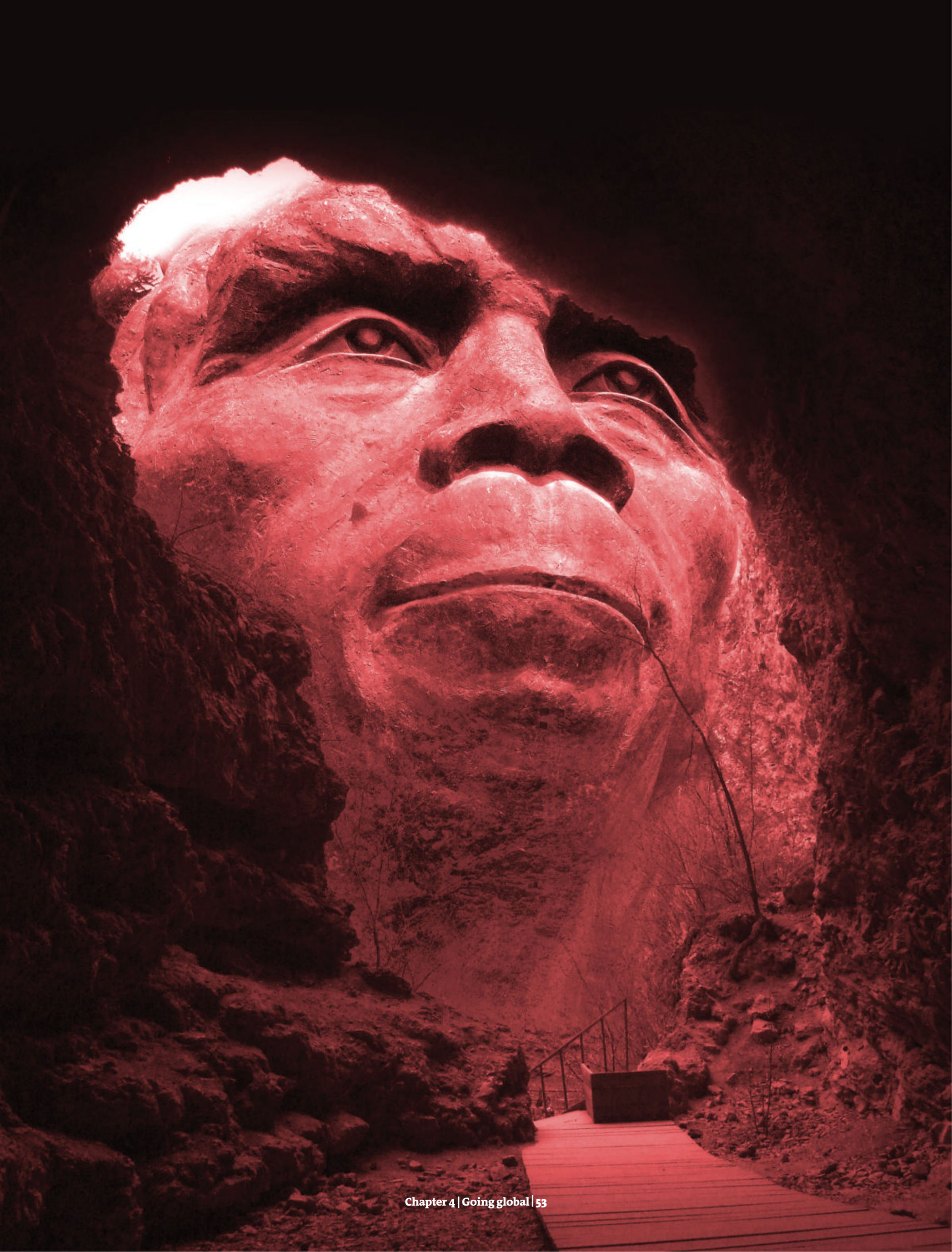
Team leader Davidson Black believed they represented a new species, which he called *Sinanthropus pekinensis*. Peking Man, as it is more commonly known, caused a sensation, triggering declarations that the cradle of humanity had been found.

Today, we know that Africa, not Asia, is our ancestral home. Peking Man is recognised as an early member of our genus, *Homo erectus*, which migrated all the way to South-East Asia as early as 1.8 million years ago. And, while nobody disputes that several human species populated Eurasia very early on, the textbook version sees them as evolutionary dead ends. Our own species, the story goes, descends directly from African *H. erectus* and only emerged from the continent some 60,000 years ago, at which point it swept across the globe, replacing all other hominin species.

As fossils continued to trickle out of Asia in the ensuing decades, they drew far less attention in the West than African fossils did, and were often dismissed because they contradicted this dominant narrative. In 1992, for instance, researchers reported finding a pair of 900,000-year-old skulls in Yunxian, central China. Their features looked like a mix of *H. erectus* and *H. sapiens* – which was odd since *Homo sapiens* was then thought to have evolved entirely in Africa no more than 200,000 years ago. “Dali Man”, a ➤

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“Ancestral humans ventured out of Africa far earlier than we thought”

260,000-year-old skull found 14 years earlier in the central province of Shaanxi, had a similar mix of features, typical of “transitional forms” that cannot be ascribed to any well-defined species. Although the Yunxian and Dali Man fossils are particularly fine examples, many more have been found in eastern Asia.

Then, in 2009, Chinese scientists announced the discovery of a 110,000-year-old jawbone in the southern province of Guangxi. Though relatively primitive, it displayed a prominent human-like chin. The team classified it as *H. sapiens*, which would mean that our species was in Asia a good 50,000 years before we previously thought. Still, many were sceptical, reluctant to rewrite humanity’s origins. Some suggested it might have been a hybrid of *H. sapiens* with another now-extinct species – though that would still imply that humans were in east Asia. Who or what the Guangxi remains belonged to is still hotly debated.

The tide began to turn in 2015, when 47 teeth were found inside a cave in Daoxian, also in southern China. Teeth are one of the best ways to distinguish between hominin species, and these were distinctly human – belonging to our own species – not to mention very old. According to Wu Liu at the Institute of Vertebrate Paleontology and Paleoanthropology in Beijing and his colleagues, they had been lying around for 80,000 to 120,000 years. For Wu, the mounting evidence could only mean one thing: “Early modern humans were in southern China at least 100,000 years ago.”

That would put our species’ first foray out of Africa at least 40,000 years further back in time, yet this early Asian expansion hypothesis is gaining traction. “The

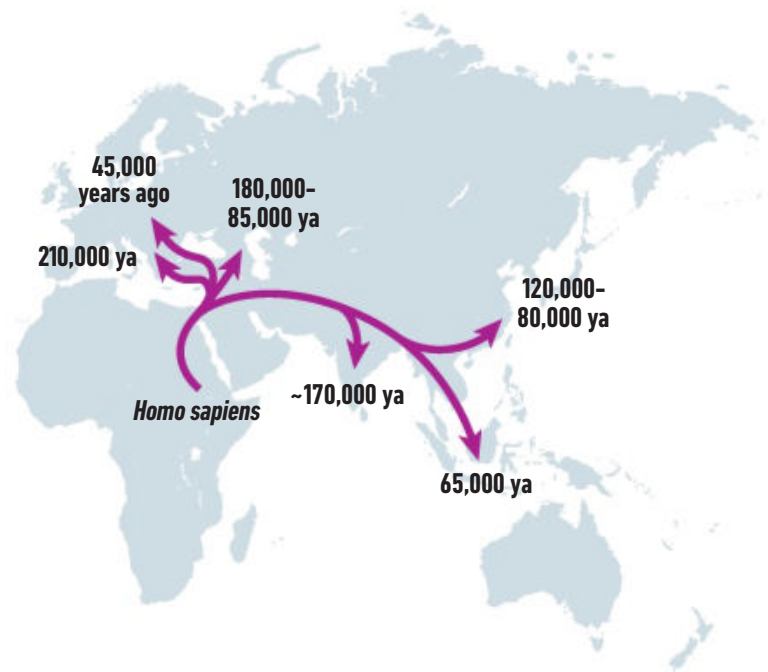
traditional view, that modern humans swept out of Africa as a single exodus 60,000 years ago is now being called into question,” says Michael Petraglia at the Max Planck Institute for the Science of Human History, Germany.

In December 2017, Petraglia co-authored a review that considers the “Asian perspective” on human evolution, drawing on all the evidence. “Palaeoanthropologists are now increasingly arguing, on the basis of fossil, archaeological and genetic evidence, that humans began spreading out of Africa by at least 120,000 years ago, and in multiple waves,” says Petraglia.

An earlier exit from Africa fits better with the realisation that our species emerged at least 300,000 years ago, adding at least 100,000 years to our history. It has also become clear that a group of *H. sapiens* was living in what is now Israel at least 177,000 years ago. Another group was making tools in south India at around the same time. And in 2018, reports of a fossilised finger bone pointed to the presence of *H. sapiens* in what is now Saudi Arabia at least 85,000 years ago. Early humans clearly weren’t the stay-at-homes we once thought.

A real jaw-dropper came in 2019, when a pair of skulls discovered in Greece in 1978 finally gave up their secrets. They were recovered from a coastal cave called Apidima, stuck together back-to-back in a block of volcanic breccia. Both were assumed to be from Neanderthals and about 150,000 years old, but a reanalysis showed otherwise. One was indeed from a 170,000-year-old Neanderthal. But the other was

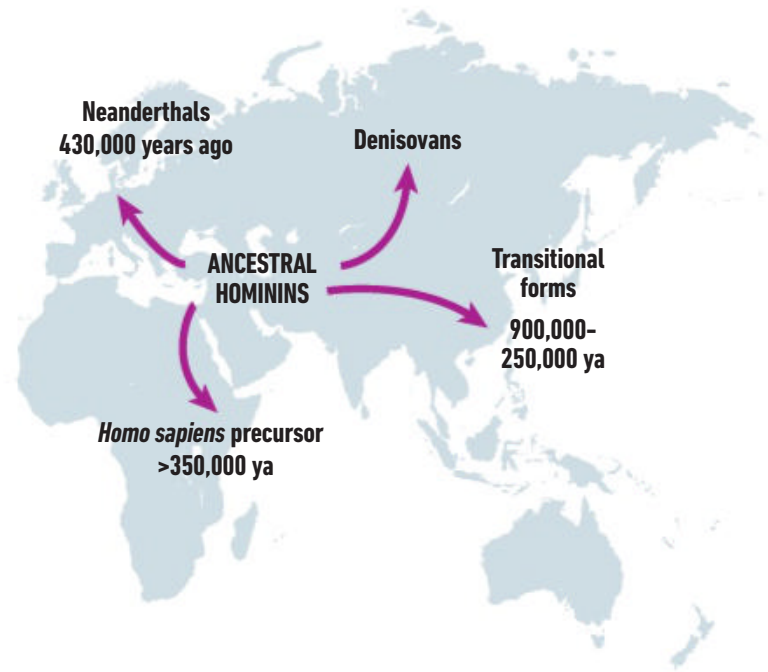
Until recently, the consensus was that *Homo sapiens* left Africa around 60,000 years ago. Growing evidence suggests the reality is more complex



210,000 years old and from a *H. sapiens*, albeit with a mixture of modern and archaic features. The skulls had somehow ended up in the same part of the cave and became stuck together some time later. The only conclusion is that modern-ish humans living in Africa more than 200,000 years ago successfully dispersed into southern Europe, a long trek by foot – or possibly raft – around the eastern Mediterranean that probably took millennia.

There seems little doubt that ancestral humans ventured out of Africa far earlier than the standard narrative allows. But this doesn't explain those weird transitional fossils from China that display a mix of *H. erectus* and *H. sapiens* features. Being hundreds of thousands of years old, they predate even our species' earlier exodus out of Africa. A radical suggestion is they are evidence that *H. erectus* evolved into *H. sapiens* in east Asia. A more likely explanation, however, is that Asia, like Africa, was once home to various human groups that exchanged genes. Along with *H. erectus*, genetic studies have revealed several other hominins whose identity is still a mystery. Later, there was the diminutive "hobbit", *Homo floresiensis*, living on the Indonesian island of Flores up to 50,000 years ago, and preceded by an ancestral species going back 700,000 years. There was also *Homo luzonensis* in the Philippines. Denisovans were probably there too: although their few identified remains were almost all found in Siberia, dental and genetic evidence indicate they were also in south-eastern Asia. Even Neanderthals, which have only been positively identified as far east as central Asia's Altai mountains, may once have roamed

According to one idea, the Middle East was home to a source population of hominins. Offshoots could have travelled far, including back into Africa where they evolved into our species



further east. Their characteristic features are now being identified in Chinese fossils.

→ Chapter 5 has more on "other" humans including the hobbit

If these various species interbred, they should have left behind hybrids scattered across Asia. Indeed, the surprisingly rich variety among east Asian fossils suggests hybridisation was widespread, says María Martín-Torres, director of the National Research Centre on Human Evolution in Spain.

Martín-Torres and her colleagues have also shown that hominins in Africa and Eurasia did evolve relatively independently for a long time. When they examined 5000 fossil teeth spanning 2.5 million years, they found that each continent had its own distinct type of teeth – strong evidence that Eurasia was a centre of speciation in its own right.

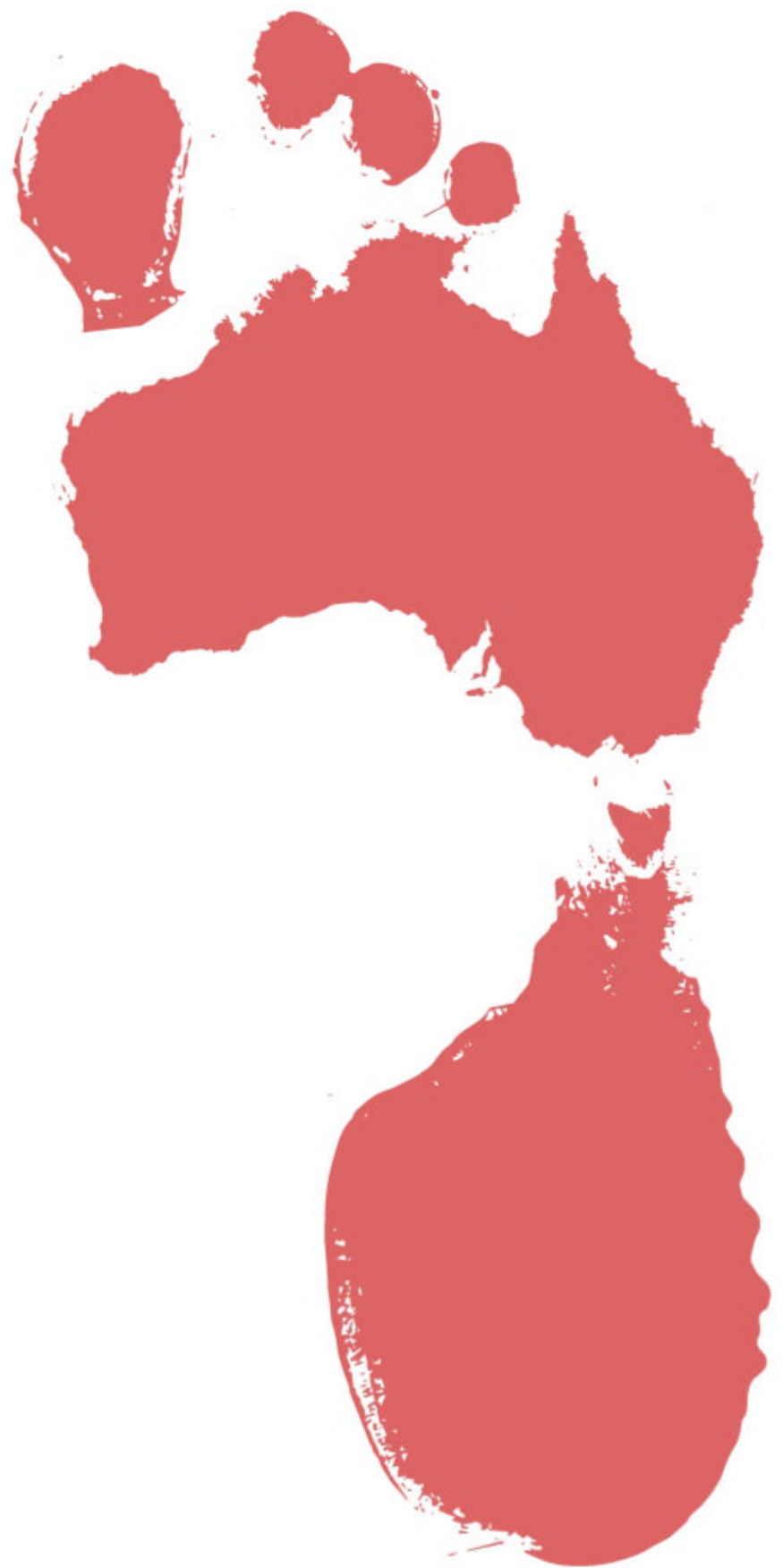
She and her collaborators suggest a "source and sink" model to explain the human settlement of east Asia. They believe the huge variety of fossils points to repeated colonisation, interbreeding and extinctions, with populations thriving and disappearing depending on fluctuations in the climate over hundreds of thousands of years. During cold periods, much of central Asia and the northern steppe would have become uninhabitable. These are the "sinks". But hominins would have been able to survive in more southerly regions, on some islands and in regions where the climate remained relatively stable, such as ➤

the Middle East – the “sources”.

If correct, this points to a strong but discontinuous occupation of eastern Asia. Although Martínón-Torres doesn't believe that our species arose independently in Asia, she does think it likely that we have roots in Asia – though probably not in the Far East. Peking Man was a true pioneer, but most of his relatives didn't travel nearly as far, settling instead in the Middle East where the climate was more favourable. This, she suggests, was the source population of Neanderthals, Denisovans and another branch of our family tree, which migrated back to Africa before evolving there into *H. sapiens*. “Maybe Africa was not the only human cradle,” she says.

These new discoveries of early dispersals are intriguing, but the big picture remains substantially unchanged. It is possible that the species we evolved from made its own migration into Africa before giving rise to us.

But nobody doubts that *H. sapiens* evolved in Africa. The current thinking is that many modern humans migrated out of Africa en masse some time after 100,000 years ago, probably via the Arabian Peninsula or the Levant or both. They gradually worked their way into Europe and along the southern coast of Eurasia, most likely in pursuit of high-quality food resources, then “back filled” into central Asia from what is now China. Around 65,000 years ago some people reached what is now Australia and New Guinea, almost certainly by boat. The last great migration then took humanity across the Bering land bridge and into the Americas around 15,000 years ago. ■



AN AUSTRALASIAN ODYSSEY

Some 65,000 years ago, early humans reached a far-flung continent that contained Australia. We once thought that crossing was accidental. Now, new evidence suggests it was planned, perhaps involving thousands of people, many rafts and great seafaring skill.

HOMO SAPIENS spread across the world almost entirely on foot. Ancestral humans walked out of Africa, through or around Arabia to south Asia, over to eastern Asia, and via various routes to Europe. They even walked to the Americas over a land bridge that once stretched from present-day Siberia to Alaska. The only major land mass that had to be reached by sea was Sahul, a lost continent that included Australia, New Guinea, Tasmania and a lot of what is now seabed.

Setting out for Sahul would have been an astonishing leap of faith. It was far offshore, requiring a voyage of many days across a chain of islands separated by deep, open sea, sometimes with little sight of land. The waters around the island groups are treacherous, and it has long been assumed that early humans didn't have the necessary tools, mental or maritime. "It's the equivalent of sending a spaceship to the moon," says Michael Westaway at the University of Queensland in Australia. "There's nothing comparable in human evolution at that time."

When Sahul was colonised, the geography of what is now South-East Asia and Australasia was quite different to how it is today. The world was in the grip of an ice age with huge amounts of water locked away in ice caps and glaciers, so the sea level was up to 85 metres lower. What is now the bottom of the Gulf of Carpentaria off northern Australia was dry land; the submerged Sahul Banks in the Timor Sea off Western Australia were coastline.

Distances were different too. These days, the journey from the southernmost tip of Asia to Australia is 463 kilometres. Back then it was just 90 kilometres. But even that is a long voyage, especially for people with only the most basic kit. At that time, our ancestors were "behaviourally modern", possessing language, symbolic behaviour, abstract thinking and creativity. However, technologically and socially, they were still firmly in the Middle Stone Age: nomadic hunter-gatherers with flint tools but no pottery, metal, agriculture, axes, wheels or domestic animals.

That goes a long way to explaining why, until recently, the prevailing view was that the sea crossings between Asia and Sahul presented such an obstacle that deliberate migration was unthinkable. People must have arrived on the currents after being washed into the sea by a tsunami or flood, perhaps clinging to a mat of floating vegetation or a raft of pumice.

This so-called "sweepstake colonisation" is often invoked to explain how terrestrial reptiles and mammals make it onto distant tropical islands, and it could plausibly account for the peopling of Sahul. Prevailing ocean currents are favourable and any floating castaways caught in them would have found the vast Sahul hard to miss. However, such scenarios are increasingly seen as unlikely – for two main reasons. Archaic humans, notably *Homo erectus*, were present in south-eastern Asia for the million years before people turned up in Sahul, but there is no evidence of them ever reaching the continent during that time. The same goes for the region's other large-bodied mammals. The other reason is demographic: ➤

OVER THE HORIZON

Ancient humans could have reached the lost continent of Sahul from south-eastern Asia via several possible routes, most of which require at least one sea crossing in which **no land was visible** at launch

- Present coastline
- Coastline 65,000 years ago



SOURCE: NATURE

even if people were accidentally swept alive to Sahul, they were vanishingly unlikely to have arrived in sufficient numbers to start a viable colony.

Admittedly, deliberate colonisation also seems implausible. “Nobody has put the question to bed,” says Michael Bird at James Cook University in Cairns, Australia.

One problem with working out how humans arrived in Sahul is that the timing is hazy. The ancient archaeological record is sparse, says Bird, perhaps because colonists stuck to coastal regions that are now under water. The oldest known site is a rock shelter called Madjedbebe in Australia’s Northern Territory. In the 1970s, archaeologists dated it to around 50,000 years ago. The most recent excavations have pushed that back to 65,000 years, give or take five millennia, though these claims aren’t universally accepted. The oldest undisputed date is 47,000 years ago.

But the idea that humans could have been in Sahul some 70,000 years ago is looking increasingly plausible. A recently discovered settlement on the Indonesian island of Sumatra – a possible staging post on the way to Sahul – is roughly that old, and a 2016 analysis of Australian Aboriginal DNA also points in the same direction.

In which case, the journey looks slightly less

daunting. Sea level was 10 metres lower 70,000 years ago than it was 50,000 years ago, which would have further reduced the distances involved. That isn’t a major factor in Indonesia’s Wallacea islands, with their steep coastlines. But the Sahul coast would have been significantly closer to the easternmost of the south-eastern Asian islands. That doesn’t necessarily mean the journey was deliberate, but two fresh lines of evidence seem to support the idea that it was.

The first concerns the route taken by the colonists. Archaeologists have long recognised that there were two plausible options. The northern route begins on the island of Sulawesi, hops across other islands of Wallacea and makes landfall in Sahul on the western tip of New Guinea. The southern route starts on the Indonesian island of Java, which would have been part of the Asian mainland then, traverses the Lesser Sunda Islands to Timor, then either heads south to the coast of Sahul or continues east to the edge of the – now submerged – Carpentarian Plain.

Even at the lowest sea level, both routes require at least one crossing approaching 100 kilometres and several of 20 to 30 kilometres, says Bird. That puts the destination over the horizon. With no knowledge of the curvature of the planet, how did people know that Sahul was even there? It is possible that they

“Two fresh lines of evidence support the move towards Australia being deliberate”

climbed headlands or peaks to scan for distant land, or inferred its existence from clouds, smoke, migrating birds or the glow of bushfires. Even so, at some point, it appeared that they would have had to strike out into the unknown.

Both routes have their pros and cons. The northern route has fewer crossings, a shorter overall distance and plenty of the wide-stemmed bamboo that is considered ideal for raft building.

But the islands would have been heavily forested, making it hard to climb to vantage points, and prevailing north-south currents would have made it tricky to maintain the correct heading.

The southern route, by and large, has shorter crossings, although the final legs would have been longer than any on the northern route. The vegetation was savannah, which is better for reaching higher ground but worse for raft-building material. On this route, the ancient mariners would have to have used a material other than bamboo, or perhaps brought stockpiles, both of which seem unlikely.

Deciding which route was more likely depends on a detailed understanding of the ancient ocean currents and climate. In 2019, Bird’s team used computer modelling to drop virtual castaways at 17 possible crossings, then allow the currents and winds as they

would have been 65,000 years ago to do their stuff. This confirmed that the possibility of randomly colonising Sahul is vanishingly small, unless implausibly large numbers of adults were being washed into the sea at unreasonably high frequencies. But it also revealed that throwing in a bit of planning – such as paddling a raft and setting off during optimal weather and currents – dramatically increases the chances of success.

Bird’s team also reanalysed visibility along the two routes. Contrary to previous work, they discovered a number of ways of navigating from south-eastern Asia to Sahul without ever losing sight of land.

All of these are on a northern route, which affords uninterrupted views of the high mountains of New Guinea; for the southern route, all of the final crossings would have had no sight of land. This doesn’t rule out the southern route, says Bird, especially when sea level was very low and there were islands south of Timor. But it does suggest that the assumption of a complete leap into the unknown no longer holds water.

The other new line of evidence supporting a planned migration comes from Corey Bradshaw of Flinders University in Adelaide, Australia, and his colleagues. They modelled the demographics of colonisation, taking account of typical hunter-gatherer fertility rates and longevity and the ecological conditions ➤

they would have encountered after landing in Sahul. The calculations revealed that the minimum founding population was 1300 people, perhaps all at once or in smaller groups over many years, which all but rules out accidental colonisation.

The peopling of Sahul was “probably planned”, Bradshaw concludes. Bird agrees. “It is not feasible that people randomly got there,” he says. “They had to think about it and they came in large numbers.” Why they came is a different question. But the chances are they were driven by dwindling resources, or simply the lure of the unknown, says Bird.

And yet the mystery isn’t quite put to bed, says Westaway, because although the new analyses are useful, only archaeology and genetics can give us the full story. “What we are missing is ancient genomes from Sahul,” he says. These would tell us not only when people arrived in Sahul with more certainty, but also whether those people were related to the other hominins present in south-eastern Asia around the same time: *Homo floresiensis*, *Homo luzonensis* and the mysterious Denisovans.

There is no archaeological evidence that these other species made the challenging sea journey to Sahul, but genetic evidence suggests it happened. From sequencing modern human DNA, we know that there were at least two interbreeding events between our ancestors and Denisovans in the south-eastern Asia/Sahul area. One can be pinpointed to somewhere between Sumatra and Borneo, but the other is centred on New Guinea, which was part of Sahul.

Ancient genomes would clinch the deal. The trouble is that the majority of Sahul, now northern Australia, is desert. “Arid conditions are not good for the preservation of Pleistocene human DNA,” says Westaway. “If we’re going to find it, I think it will have to come from the highlands of New Guinea, but that would require new excavations.”

As for the archaeology, Bird’s colleagues are carrying out high-resolution surveys of areas of Sahul that are now underwater, looking for potential sites of early human occupation. Again, though, that would require new excavations, this time on the seabed. “Underwater archaeology gets very expensive,” says Bird. For the time being, the prospects for new archaeological discoveries seem remote. When it comes to understanding how such ancient humans were able to navigate to a new continent, we are in

the realms of speculation, says Westaway.

What we do know is that the minimum requirement is a raft of some kind, probably made from bamboo lashed together with plant fibres. But could a fleet of such rudimentary vessels really carry hundreds of people safely from Asia to Sahul?

One way to find out would be to recreate the journey, which is exactly what an experimental archaeology project called The First Mariners was set up to do. In early 2020, the researchers behind the project were on the southern tip of the Indonesian island of Rote, building a raft using stone tools and locally available materials, principally a giant bamboo known as betung which can reach 20 metres or more in height. “Almost nothing challenges bamboo for weight, strength, durability, availability, resistance to seawater and its extraordinary flotation properties,” says project director and maritime historian Bob Hobman.

The team lashed together about 250 stems to create a platform 18 metres long and 4 metres wide. The deck was supported by cross timbers foraged from the forest and held together with around 17,000 metres of rope made from the bark of the sugar palm (*Arenga pinnata*). Basic steering was provided by a rear oar, and the giant leaves of the lontar palm (*Borassus flabellifer*) formed a rudimentary sail. “It’s our secret weapon,” says Hobman. “It’s really not a sail, but it gives wind assistance. It’s unsophisticated, but it will do the job.”

The plan was to set off across the Timor Sea in early February when the north-westerly monsoon wind is brisk. Hobman had estimated that the journey would take about 14 days, crossing the drowned coastline of Sahul after about six. The 10-strong crew were to live mainly on fish and monsoon rain. And they would have a support vessel following in case they get into difficulty in the shark-infested waters.

Hobman was confident of success – because he has almost done it before. In 1998, he was part of a crew that sailed a bamboo raft called Nale Tasih 2 from Timor to within spitting distance of Australia before heavy seas forced them to abandon ship. But that vessel was built using modern tools and had a woven sail. The new expedition was designed to show that Palaeolithic humans really could have navigated to Sahul. Then, in late February, disaster struck. The project fell victim not to covid-19 but to an internal “misunderstanding” with Indonesian immigration. The crew members were deported just hours before they were due to set sail. ■

MAKING WAVES

Archaeological and genetic finds on islands and distant shores around the world hint at early maritime adventures



A deep sea floor and rapid currents mark South-East Asia's **Wallace line**. Large animals like apes and tigers could not cross it even during the last glacial maximum, when sea levels were at their lowest. Any human remains east of the line therefore suggest that a sea voyage was needed to get across

A SPAIN

1.4-million-year-old hominin bones and stone tools suggest an early human – possibly *Homo antecessor* – could have crossed from Morocco

B MEDITERRANEAN ISLANDS

Neanderthal stone tools hint that our extinct cousins sailed to them more than 130,000 years ago

C YEMEN

Stone tools dating to around 106,000 years ago suggest *H. sapiens* may have crossed from Djibouti in East Africa

D JAPAN

Genetic studies and signs of human occupation in caves indicate that *H. sapiens* had made it to Japan by at least 38,000 years ago

E PHILIPPINES

700,000-year-old stone tools and butchered rhino bones suggest early hominin occupation, possibly by *H. erectus* or Denisovans

F SULAWESI, INDONESIA

Stone tools point to an early human species having made it to the island more than 118,000 years ago

G PAPUA NEW GUINEA

Denisovan DNA in people with Papua New Guinean and Australasian ancestry suggest the Denisovans reached Papua more than 600,000 years ago

H AUSTRALIA

Stone tools, ancient fireplaces and pigments used in rock art near the northern coast all point to *H. sapiens* arriving 65,000 years ago, presumably from Indonesia

I FLORES, INDONESIA

Hominin bones and stone tools on the island suggest an ancestor of *H. floresiensis* made the crossing more than 700,000 years ago

INTO THE AMERICAS

The Americas were the last continents conquered by humanity. However, before the pioneers ventured south, their forebears had spent millennia scratching a living in the desolate regions of the Arctic circle. Who were these original frontiersfolk and how did they survive?

WE DON'T know exactly when humans first reached the New World. The consensus is that the first Americans arrived fairly recently, about 15,000 years ago. It is also widely believed that they did so via Beringia – an area centred on the Bering Strait between Siberia and Alaska, which was dry land at that time.

This implies that the story of the first Americans began with a subarctic odyssey. Although Europe and Asia has been home to hominins for almost 2 million years, it seems none of the earliest inhabitants – including *Homo erectus*, Neanderthals and Denisovans – strayed much above 55° north, roughly in line with the top of what are now Ireland and Kazakhstan. There's every reason not to do so: it isn't just cold, there also aren't as many animals at higher latitudes, making hunting difficult.

On current evidence, modern humans, rather than our extinct relatives, were the first to enter northern Eurasia. John Hoffecker at the University of Colorado, Boulder, suspects that key inventions opened up this subarctic region. Tailored clothing was probably necessary to cope with cooler conditions. And snares offered a solution to sparsely distributed prey. Used

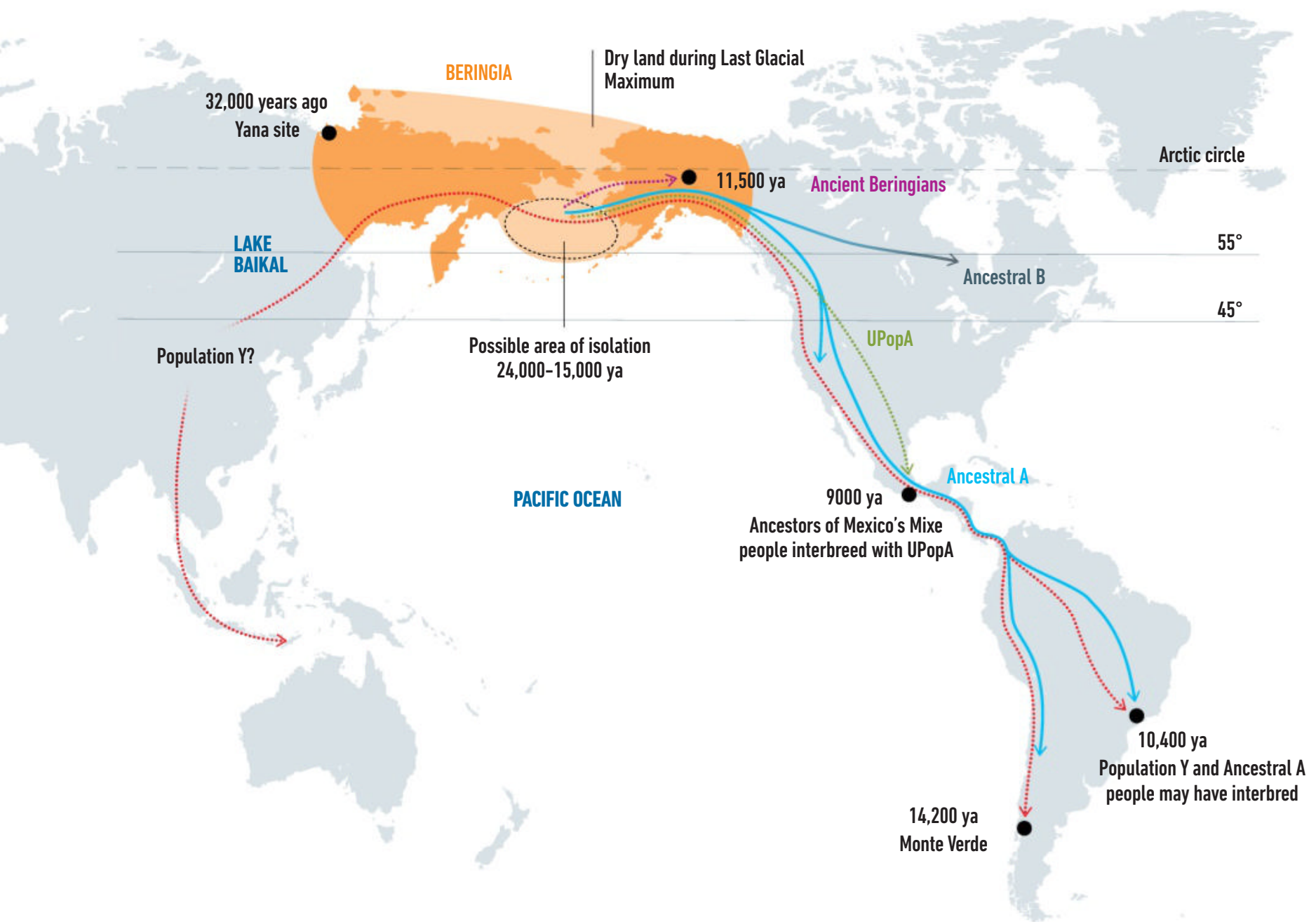
by modern Arctic inhabitants, they are essentially automated hunting devices that operate 24 hours a day, helping people exploit territories covering thousands of square kilometres.

There are disputed signs of human activity in northern Eurasia 45,000 years ago. But it is at a 32,000-year-old site in the Arctic circle that the archaeological record really takes off. On the banks of the Yana river in Siberia, at the western end of Beringia, archaeologists have found hundreds of stone and bone tools, including sewing needles. The people near the Yana hunted reindeer, woolly rhinos and birds. Hares were also caught, perhaps for their pelts, if modern Arctic peoples are any guide.

Life in Beringia wasn't unrelentingly grim. Those inhabiting the Yana site had time for artistic pursuits: it has yielded dozens of beads carved from ivory and bone. Archaeologists also found strips of decorated ivory that may have been used as hairbands, and shallow ivory dishes that perhaps served ritual purposes.

There were human remains at the site as well – two tooth fragments – and both contain preserved ancient DNA. The teeth belonged to children who were part of a population related to, although not directly ancestral to, modern Native Americans. But the game-changing discovery was about the size of the community. These children were so genetically distinct from each other ➤





THE PIONEERS OF A NEW WORLD

Hardy subarctic people lived near the Yana river some 32,000 years ago. It was at the edge of an area known as Beringia, which included dry land between what is now Siberia and Alaska. Then Earth began to cool and ice spread, trapping people in this habitable oasis. Isolated from the rest of humanity, Beringians developed distinct genetic variants that can help track how populations of them moved into the Americas 15,000 years ago



that the Yana population may have numbered more than 500.

It is a startling finding, says Hoffecker. The Yana site was remote from the southern centres of human activity in the late Stone Age, so we might expect the population to have been tiny, isolated and inbred. “But it’s a fairly healthy and robust group,” he says. This suggests there was a degree of migration into and out of Beringia, keeping populations there genetically diverse. But even though this group may have been flourishing, there is no good evidence that these people pushed further east, despite Siberia and the Americas then being connected by dry land.

There they stayed for generations. Then, about 30,000 years ago, Earth began to lurch into a severe cold snap called the Last Glacial Maximum. Ice sheets grew across North America, and the route from Beringia to the New World froze shut. It was some 15,000 years before conditions began to improve and the route reopened. The Yana site was abandoned at the beginning of this period.

However, it seems that other groups stayed in Beringia. A decade ago, geneticists including Ripan Malhi at the University of Illinois discovered subtle genetic differences between living Native Americans and East Asians that originated thousands of years before people entered the Americas. The geneticists suggested a solution: perhaps the ancestors of the Native Americans had lived in Beringia, and become isolated as temperatures dropped 30,000 years ago. Their route south was blocked by polar deserts in Eurasia and ice sheets in North America. In theory,

Extraordinary human remains have been found near the Yana river in Siberia



ELENA PAVLOVA

these people could have been cut off from the rest of humanity for 15,000 years, plenty of time for random genetic drift to give them distinctive DNA before they entered the New World. The idea was labelled the Beringian incubation or standstill.

Today, most researchers accept that there was an incubation period, although they now think it didn’t begin until about 24,000 years ago, when conditions got really bad, and that it lasted 9000 years at most. However, there is disagreement about where exactly this period of isolation happened.

Some are convinced that the ancestors of today’s

“The original Americans may have been cut off for thousands of years”

Native Americans did, in fact, retreat south as conditions worsened, and spent the Last Glacial Maximum near Lake Baikal at approximately 53° north. We even have DNA from a boy who died there 24,000 years ago. Like the Yana children, he was related, although not directly ancestral, to the Native American founding population. But other researchers, including Hoffecker, are convinced that the incubation occurred in Beringia itself. The region’s geographical remoteness makes it a more likely place for a population to be isolated for millennia, they argue. Indeed, there is genetic evidence that this happened to other mammals – including elk and brown bears – during the Last Glacial Maximum.

Another clue comes from linguistics. There are similarities between some of the languages spoken in the Americas and Ket – a Yeniseian language spoken in Siberia to the west of Lake Baikal. A language family tree indicates that the oldest representatives of this group were spoken near the Beringian region, suggesting this is where it arose. Ket speakers may be descendants of Beringians who migrated back into Siberia after the Last Glacial Maximum.

Hoffecker points to more reasons why an extended stay in Beringia makes sense. As Earth’s climate cooled and ice sheets began to form, global sea levels dropped dramatically. By 28,000 years ago, the seas may have been 100 metres lower than they are today. As a result, thousands of square kilometres of new land appeared in south-central Beringia. And not just any old land. Although most of the subarctic became cold and arid after 30,000 years ago, climate models and pollen

records indicate that this region was humid and mild, perhaps because Pacific currents pushed warm air over it. “There’s no other place on Earth where you got this significant expansion of viable habitat during the peak of the Last Glacial Maximum,” says Hoffecker.

Considering Beringia’s size and its benign climate, one estimate suggests that tens of thousands of people could have lived there during the peak of the Last Glacial Maximum. They would have faced big challenges, though. Anyone living above 46° north will struggle to get the sunlight they need to trigger vitamin D synthesis in the skin during winter. “Even if you’re naked outside, you’re not going to get enough ultraviolet light exposure,” says Leslea Hlusko at the University of California, Berkeley. Adults can largely overcome this problem by eating vitamin D-rich foods such as oily fish, but nursing infants would be at risk of vitamin D deficiency, which can weaken the immune system and cause skeletal problems, among other things. She thinks evolution found a solution.

One variant of a gene called *EDAR* changes the density of milk ducts within the female breast. Hlusko suspects that this boosts the transfer of nutrients, including vitamin D, from mothers to their infants. The same *EDAR* variant also leaves people with strikingly thick enamel on the tongue side of their incisors. So she, Hoffecker and their colleagues looked at the global distribution of these curious teeth. They are all-but absent in most regions, present to some degree in east Asia – and almost ubiquitous among current and past Native American populations. To Hlusko, this fits with the idea that the ancestors of Native Americans, ➤

isolated in Beringia, evolved the *EDAR* variant, which helped them overcome their vitamin D problem and gave them thicker tooth enamel as a side effect.

Tábita Hünemeier at the University of São Paulo, Brazil, also thinks the Native American founder population was isolated in Beringia – and that it evolved in response. In 2017, Hünemeier and her colleagues discovered that people in many present-day Native American populations carry unusual versions of a family of genes called *FADS* genes. People with these variants are better able to process the protein and fatty acid-rich diet that subarctic communities typically consume. The variants may have been naturally selected in the Native American founder population while it was isolated in Beringia, says Hünemeier.

All this research is building a picture of life on the American frontier. But until recently, the Beringian incubation was generally viewed as little more than a curious prologue to the story of the first Americans. This held that the real epic began about 15,000 years ago when the ice sheets retreated and a small, genetically homogeneous population moved from Beringia into the New World. By 14,600 years ago, the founding population had split into two distinct Native American subpopulations. One, the Ancestral B group, apparently stuck largely to the very north of North America, where many of its descendants still live today. The second, the Ancestral A group, gave rise to a famous North American prehistoric culture, the Clovis, and also spread south into Central and South America over the next couple of millennia.

Or that's what we thought. But within the past couple of years, we have learned that the Beringian people fractured into subpopulations during the incubation period. This means that several genetically distinct



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Native Americans trace a history on their continent stretching back 15,000 years

groups moved into the New World. The clearest evidence for this comes from DNA locked in the bones of two children who were buried in Alaska, 11,500 and 9000 years ago. Both belong to a genetic group – the Ancient Beringians – that split from the rest of the Beringians about 22,000 years ago. The idea that this happened in Beringia and the two subpopulations then avoided mixing for thousands of years isn't as implausible as it might seem. Malhi points out that tree species in Beringia went through a similar population fragmentation during the Last Glacial Maximum. Perhaps populations became isolated because each adapted to a unique microclimate within the area, he suggests.

At present, there is no evidence that the Ancient Beringians made much of a contribution to the peopling of the New World. Even after the ice sheets retreated, they seem to have lingered in the Beringia region, eventually vanishing when populations of Native Americans from further south pushed back north into Alaska. However, this may not have been the only subpopulation to branch off during the Beringian incubation. And others might have had a greater wanderlust.

In 2018, researchers reported that the Mixe people of Mexico carry a genetic signature unlike that of their neighbours. One interpretation is that, about 9000 years ago, their ancestors mingled with a mysterious group, provisionally dubbed UPopA, which seems to be another subpopulation originating in Beringia some 25,000 years ago.

Then there is the enigmatic Population Y. In 2015, geneticists announced that some members of the Suruí and Karitiana groups living in the Amazon share a curious genetic connection with some Indigenous

Australasians. The simplest explanation is that this originated in a prehistoric east Asian group, Population Y, which was ancestral to the first Australasians and also contributed genetic material to the New World via Beringia.

However, geneticists have found no signs of Population Y in ancient DNA from Beringians or North Americans, and some researchers began to doubt its existence. Then, in 2018, came the discovery that a person who died in eastern Brazil 10,400 years ago carried the Australasian-like DNA. The individual belonged to the Ancestral A line of Native Americans that we know came to occupy South America. Given that Population Y DNA hasn't been found in Ancestral A remains in North America, the geneticists suggest the two groups met and interbred after they arrived in South America. They say this might indicate that Population Y Beringians were the very first people to push into South America. If so, the inhabitants of early sites there – such as the 14,200-year-old Monte Verde in Chile – left a genetic legacy.

No doubt, in the coming decades, we will learn more about the peopling of the Americas. As with the rest of our human origins story, this part is being rewritten. For now though, research from genetics, fossils and ancient artefacts has given us a glimpse into the lives of the first Arctic settlers. Some 15,000 years ago, these original frontiersfolk stood on the threshold of a new world. To the south were the Americas, 40 million square kilometres of virgin territory including wide-open prairies, dense rainforests and high mountain chains. Humanity's last major migration was about to begin. It was the final step in an epic journey of an intelligent ape that originated in Africa more than 7 million years ago. ■

CHAPTER 5

THE "OTHERS"



As we have seen in previous chapters, fossil and DNA evidence suggest that our ancestry isn't so much a family tree as a tangled family bush, with many more branches and interconnections than we knew.

We have very little evidence of what life was like for most of these other hominins. But for a few more recent members of our family that we've already encountered – the Neanderthals, the Denisovans and the diminutive “hobbit” – we are putting together a richer picture.

HOMO NEANDERTHALENSIS: NOT SO BRUTISH?

Neanderthals are perhaps the best known of our hominin cousins. However, in recent years, our conception of them has been transformed by new discoveries. Where once we saw them as stocky, dim-witted ersatz humans, now we know that they had remarkable capabilities. Nowhere is this clearer than in their domestic lives.

THERE has long been an assumption that “home” is a uniquely human concept. While other animals may have permanent or semi-permanent dwellings, there is so much more to our concept of home. Its invention marked a critical threshold in the long march towards civilisation. As well as being a practical advance, it was also a conceptual leap that shaped the way

our ancestors thought and interacted.

However, as archaeologists have begun to search for evidence of home on the ground they have found something surprising: home wasn’t exclusively the domain of *Homo sapiens*. But *Homo neanderthalensis* may have been the original homebodies. Far from being brutish, they may have enjoyed nothing more than spending time indoors around a cosy fire, doing a spot of DIY and inviting friends over for dinner.

For most of prehistory, there is almost no evidence of human presence in caves or rock shelters. Early humans instead must have occupied less permanent dwellings, but the ephemeral nature of organic matter means that the archaeological record is mostly silent on their whereabouts. Then, starting around 400,000 years ago, something changes. “It’s something that sweeps across the hominin world,” says archaeologist Clive Gamble at the University of Southampton, UK. “It spreads like a virus, reorganising and changing as it goes.”

Matt Pope an archaeologist at University College London thinks he knows what changed. Given that more-permanent dwellings appear then, he thinks ➤

PREVIOUS PAGE: HALAMKA/ISTOCK PHOTO
RIGHT: LORENZA PHOTOGRAPHY/ALAMY



that “something” was the notion of home. It is hard to say which species of hominin had the idea and, like most abstract concepts, that of home probably took time to coalesce. However, there is no doubt that, in Europe, the transformation got under way long before 45,000 years ago, when modern humans arrived from Africa. Only Neanderthals could have been responsible.

Necessity may well have spawned this particular invention, because the Europe that Neanderthals inhabited from at least 500,000 years ago was far colder and more arid than it is today – and after 180,000 years ago, it became colder still, with temperatures falling to -20°C at times, and not rising above 12°C even in summer. But there must have been more to homemaking than necessity. After all, hominins began producing tools more than 3 million years ago. They were hunting and sharing meat in family groups for generations, but they weren’t living at their butchery sites because the mess and smell would have attracted scavengers, making them dangerous places to linger. A cave or rock shelter could have contained the smell while allowing its occupants to control access and stay safe, so why didn’t they take advantage of this?

Pope suspects the key was fire. It is very difficult to tell whether a prehistoric population could make fire, he notes. The archaeological record suggests that *Homo erectus* may have started using it a million years ago or more, but it is only around 500,000 years ago that our ancestors appear to control fire. Hearths have been found at many Neanderthal sites, some containing burnt bones. Armed with light and a means of warding off dangerous animals, Neanderthals could bring sleeping and food-sharing

activities together in a single space – home.

Put Pope in a valley apparently untouched by humans and he can tell you where Neanderthals would have built their home. “It’s about a third of the way up a slope, with a really good vista and a solid bit of rock behind,” he says. Anyone who goes camping will recognise these preferences: this is where you want to pitch your tent when you arrive in an unfamiliar place at dusk. It is also where aspirational types dream of buying a place to live. In other words, this is the spot that lures us too with siren calls of home.

As it is for us, so a Neanderthal’s home was a refuge. To provide shelter from the elements and from predators, their preference was for a dwelling that backed onto solid rock with entrances arranged in such a way that access could be managed. In general, they spurned the depths of caves as living spaces, staying close to their mouths. It is lighter there, but also draughtier. At the 70,000-year-old site of Tor Faraj in southern Jordan, they piled up stones and wood to create windbreaks inside the shelter. Later, they began building windbreaks in the open, using wood and even mammoth bones. At La Folie, a 60,000-year-old site near Poitiers in France, post holes preserved in sediment point to some kind of circular wooden structure, perhaps covered with skins or brush.

Neanderthals certainly had the technical skills to construct dwellings. They had mastered the art of combining different materials, binding stone points to wooden hafts with animal sinew or plant fibre to make spears, for example, and sealing the joints with resin or birch bark pitch. They worked animal hides too, turning them into leather and stitching them together with long strips of hide, so they could have made simple

“As it is for us, so a Neanderthal’s home was a refuge”

tents. By lighting a fire inside a tent, they could have raised the temperature from -20°C to 20°C and, through such engineering of their environment, endured a cold winter night. “For hundreds of miles around, there isn’t going to be any bubble of warm, survivable air other than the one the Neanderthals have managed to capture and seal,” says Pope.

As well as being cosy, other aspects of Neanderthal homes would have been familiar to us. “Early living spaces are being divided into separate activity areas right from the beginning,” says Pope. Rocks and animal bones were used to demarcate those proto-rooms, and though organic materials such as wood or hide have generally not survived, the rock alignments could have supported partitions made of these. Above all it was fire – the hearth – that structured the space, and this is seen most clearly at a Neanderthal rock shelter near Barcelona in Spain, known as the Abric Romaní.

It opens out of an escarpment above a valley that would have been rich in vegetation and the kinds of stone that Neanderthals used to make tools. The valley would also have provided passage for deer, horses and a now-extinct ox called an aurochs migrating inland from the coast – useful for hunting. It was inhabited on and off for at least 70,000 years, until about 40,000 years ago, probably by family groups of 10 to 20 individuals each time.

The site is very well preserved because periodic flooding evicted the occupants and deposited minerals that make it easy to date the interleaved, sandy layers containing evidence of human habitation. Since excavations began in 1983, archaeologists have dug down more than 10 metres, uncovering 17 levels that represent different phases of occupation.

To understand how Neanderthals organised their domestic space, María Gema Chacón at the Catalan Institute of Human Palaeoecology and Social Evolution in Tarragona, Spain, and her colleagues have uncovered most of the 300-square-metre floor at each level. One level, dated to 58,000 years ago, contains more than 40 hearths – the most they have counted in any of the levels. “My students go down there and they’re amazed,” says Chacón. “You can still smell the roasted deer.”

At each level, the arrangement of hearths is the same. “There are small ones, not more than 50 centimetres in diameter, around the outside, and much larger ones in the centre,” she says. The small hearths are located between 1 and 2 metres from the walls, and the inhabitants probably slept and rested in that gap. Chacón’s group has found fossilised plant remains there, possibly traces of grass they brought in for bedding. The larger hearths would have been reserved for daytime activities, including knapping of tools and processing the spoils of hunting, and may have been constructed specially for each function. One kind is surrounded by stones, for example. In another, stones were placed under the combustible material to create more smoke – perhaps for smoking meat. A third comprises a shallow depression in the ground that could have been filled with water into which hot stones were dropped to boil it for cooking, or to generate steam. It seems that Neanderthals were quite sophisticated cooks. Digs have found evidence suggesting they boiled bones to extract nutrients, flavoured their meat with wild herbs such as yarrow, and even adopted a vegetarian diet on occasion.

Life around the hearth is likely to have affected



social interactions. Anthropologist Polly Wiessner at the University of Utah has described how fire helps structure the social lives of modern San people of southern Africa, and has drawn parallels with human ancestors. During the day, the talk in camp is all gossip, complaint and practical exchanges of the “What’s for supper?” kind. After dark, people gather around a single hearth, and the conversation turns to myth and stories. “They’re using the extra time that fire allows to talk about the things that really matter to humans, the things that bind emotionally,” says Gamble. The fire also provides opportunities for non-verbal communication in the form of eye contact and who sits where, and for other social bonding activities such as singing and dancing. There is no reason why it couldn’t have done the same for Neanderthals, he adds. At the Abric Romaní site there are even hints that the occupants had dinner guests. Around certain hearths, says Chacón, the quantity of animal bones suggests a large gathering.

A home would have influenced social interactions in another way, too. There has been a tendency to imagine the past as populated exclusively by healthy adult males, says archaeologist Penny Spikins at the University of York, UK. But groups would have included toddlers, pregnant women, older people and sick people – and injury rates from hunting large animals at close quarters would have been high. Neanderthals cared for each other when sick or wounded, and they assisted with childbirth. They probably dressed wounds – perhaps with lemming skins, as the Inuit once did – and disinfected them with antiseptics including ochre. Their medical cabinet included painkillers and penicillin too. All this ministering

implies that they had a place where they could remain sedentary – and safe – for extended periods. “Home is that intimate place where you can feel supported and comforted and looked after,” says Spikins.

Neanderthals buried their dead under the floor of their caves or shelters, something that *H. sapiens* were still doing much later in the Neolithic period. Both groups also practised cannibalism, perhaps for ritual rather than nutritional reasons – “possibly the ultimate caring act”, says Gamble. Unlike their human contemporaries, Neanderthals don’t seem to have buried their dead in the open – perhaps another indication of the significance they attached to home.

We don’t know whether Neanderthals were the first homemakers. There is plenty of evidence that *H. sapiens* was building similar shelters and inhabiting rock dwellings at much the same time. Their open-air camps soon took on a feel of semi-permanence, unlike those of Neanderthals, who kept moving in a seasonal round. But Neanderthals often returned to favourite caves and once there they lit fires and bedded down where they always had. Gamble likens such behaviour to the well-worn gestures we all make on returning home – switching the lights on, drawing the curtains and so on. “There is a memory there,” he says. “That sort of repetitive behaviour is very like ours.”

One thing that has yet to be found in Neanderthal homes is anything resembling what is seen as art in the context of their *H. sapiens* contemporaries. That’s not to say they were incapable of artistic creations. Mysterious arrangements of snapped-off stalagmites were discovered a few years ago in the pitch-black depths of Bruniquel cave in south-western France. These enigmatic structures, built by Neanderthals

WHERE DO THE NEANDERTHALS FIT IN?

Named after the “type specimen” discovered in Germany’s Neander Valley in 1856, the first fossils now ascribed to the species *Homo neanderthalensis* were discovered in 1829. The species wasn’t officially named until 1865, but the Neanderthals’ fame is in part due to their status as the first extinct ancient human species to be discovered – several decades before Darwin put forward his theory of evolution by natural selection.

We have now found bones from hundreds of Neanderthals in countries across Europe, western Asia and central Asia. It seems the species appeared in Eurasia roughly 200,000 years ago and went extinct there about 40,000 years ago. *Homo neanderthalensis* is sometimes labelled the “cousin” of our species, *Homo sapiens*. Both species seem to have shared the same “parent” species – an early human that some researchers identify as *Homo heidelbergensis*, which, in turn, was possibly a descendant of *Homo erectus*.

Exactly when the line leading to *H. sapiens* split from the one leading to the Neanderthals is still being debated. Some recent research suggests the split happened more than a million years ago, with a Eurasian branch eventually evolving into the Neanderthals (and the Denisovans) while an African branch evolved into *H. sapiens*.

around 175,000 years ago, are formed from some 400 stalagmites and include one ring 7 metres across. However, this doesn’t seem to have been a living space. Meanwhile, Pope is reluctant to attach the label “art” to the large piles of mammoth bones his group found at a cave called La Cotte de Saint Brélade, a Neanderthal home in Jersey, in the Channel Islands, even though some of the piles are so well ordered it is tempting to seek meaning in their structure.

That doesn’t signify that Neanderthals were incapable of symbolic thought. In 2018, João Zilhão at the University of Barcelona in Spain revealed that some living in the Iberian peninsula painted caves at least 65,000 years ago and their own bodies at least 115,000 years ago. Perhaps they felt less need to broadcast their symbolism than modern humans did, or perhaps it took different forms and served different purposes. For example, it is possible, says Gamble, that the stalagmites in Bruniquel form a prehistoric xylophone on which Neanderthals made music.

For Zilhão, the emerging story of Neanderthal domesticity is the logical culmination of the reassessment of who they were. They may have looked different, he says, but they were “just humans” living at a time when anatomical diversity among human groups was greater than it is today. Spikins agrees. The rethink began with clues that they buried their dead, but the watershed came with the discovery that modern humans and Neanderthals interbred, she says. “Suddenly it was much more acceptable to see their more humanlike qualities.” All this firmly overturns the idea that Neanderthals were brutish. “A more accurate reconstruction would come from *The Flintstones*,” says Pope. ■

THE MYSTERIOUS DENISOVANS

If Neanderthals weren't the dolts we had thought, what about their recently discovered sister species, the Denisovans? Despite the lack of physical remains, the objects they produced give us a remarkable insight into their technological abilities.

QUITE apart from other things, the Denisovans, who are thought to have lived possibly throughout eastern Asia between about 200,000 and 50,000 years ago, are important for the way they were discovered. All other extinct humans are what researchers call “morphospecies”: we know they were distinct species because their skeletons look different from ours, and from the skeletons of other extinct human species. The Denisovans are different. We know almost nothing about their skeletons, their appearance, or how they behaved.

In fact, the Denisovans were “discovered” in a genetics lab. With advances in genetic sequencing, researchers can now extract and sequence human DNA from bones that are hundreds of thousands of years old. That's what researchers were doing in 2010 when they analysed DNA samples pulled from fragments of 50,000-year-old human teeth and bone found in a cave in southern Siberia.

Denisova cave, high up in the Altai Mountains, is named after a hermit called Denis who lived in it during the 18th century. Human habitation there stretches back much further though, as Russian palaeontologist Nikolai Ovodov discovered in the 1970s when he visited, looking for remains of cave bears, and found ancient stone tools. Excavations have since revealed a human presence, on and off, over the past 300,000 years. Hominin fossils are rare but by 2008 archaeologists were convinced that Denisova cave had



been home to Neanderthals as well as to early modern humans. That is why, when Michael Shunkov from the Russian Academy of Science found a tiny fragment of a finger bone, he assumed it must belong to a Neanderthal.

Everyone was surprised when genetic analysis revealed the shard to be from an entirely new group of ancient humans, the Denisovans. Being able to identify one of our ancestors from DNA marked a milestone in palaeoanthropology. Further genetic analysis has indicated that as much as 765,000 years ago, Denisovans shared a common ancestor with the Neanderthals and our species, *Homo sapiens*. Once this ancestral population had split, our branch of the human family tree stayed in Africa while the Neanderthal/Denisovan one moved into Eurasia. By roughly 430,000 years ago, the Eurasian branch had itself split, ultimately giving rise to the Neanderthals mostly in western Eurasia and the Denisovans in the east.



Turn back to chapter 3 for more on palaeogenetics

We still have very little idea of what Denisovans looked like. The fossil record of these mysterious humans remains extraordinarily sparse – comprising just four fragments of bone and teeth and a jawbone found in Tibet. But we have learned a lot about Denisova cave in excavations stretching back over the past four decades. The site has become a major draw for archaeologists, with Russians continuing to lead the investigations. Over the years, they have excavated several metres of

sand and dirt from two of the cave's three chambers – the main and east chambers – and they have more recently started excavating the third, the south chamber. To date, they have uncovered almost 80,000 stone artefacts produced over a 150,000-year period.

Dating these objects is not straightforward. It is often extremely difficult to work out the age of dirt layers in caves, according to Richard Roberts at the University of Wollongong, Australia, who got involved in investigations at the site in 2011. “You don’t have nice and simple layers one after the next after the next, with nothing happening afterwards. Things happen in caves,” he says. Most obviously, animals including hyenas moved into the cave whenever hominins abandoned it. In the process of digging their dens, the hyenas mixed up some of the dirt layers in a few sections of the main and east chambers. Complicating things further, there are some significant time gaps in the sequence. For instance, using an optical dating method that establishes the age of sandy deposits from when they were last exposed to sunlight, researchers have found that a 60,000 to 70,000-year-old layer lies directly beneath a layer that is no more than 44,000 years old.

That is particularly unfortunate because some of the most noteworthy finds from the cave – those known as the Initial Upper Palaeolithic artefacts – come from layers of dirt that lie very close to this time gap, making it difficult to be sure how old they are. These include a bracelet of polished green rock discovered early in the 2000s. The only way to work out its age would be to use optical dating on sand grains immediately around it. But such grains weren’t gathered when the bracelet ➤

was found so we may never know when it was made. Sand grains are now routinely collected alongside all Initial Upper Palaeolithic finds. The archaeologists have, however, unearthed rings, beads and bone sewing needles from the Initial Upper Palaeolithic. A few bone pendants have now been carbon-dated. The oldest are about 45,000 years old, perhaps the oldest such artefacts in Eurasia.

But which human inhabitants of the cave made them? Research published in 2019 concludes that Denisovans and Neanderthals both lived there at several points over the past 300,000 years, and *H. sapiens* probably occupied it within the past 50,000 years. “We think that the Initial Upper Palaeolithic bone artefacts recovered from Denisova cave were produced by the Denisovans,” says Shunkov, who leads the investigations. It is certainly possible, says Roberts. Neanderthals would have been long gone from the cave by this time, but the youngest of the Denisovan bone fragments found there appear to be just 50,000 to 55,000 years old. “The Denisovans did persist at the cave until quite recently – certainly recently enough that they could have made some of those Initial Upper Palaeolithic artefacts,” he says.

A study published in 2020 supports this contention, suggesting that Denisovans had the technological capability. Maxim Kozlikin at the Russian Academy of Sciences in Moscow and his colleagues studied 37,000 of the 60,000 stone tools found in the east chamber to get a sense of technological evolution at Denisova cave. The oldest specimens are in dirt layers more than 200,000 years old, according to optical dating. These artefacts show that the cave’s inhabitants used the so-called “Levallois technique” to make tools. This relatively sophisticated technique was popular across Africa and Eurasia at the time, and involves carefully chipping at a stone to remove flat flakes with sharp edges that could be used as tools.

By about 150,000 years ago, however, the people

using Denisova cave were shifting away from producing flakes. They began using the Levallois technique to produce narrow, parallel-sided stone blades, some about 3 centimetres wide and 10 centimetres long. This marks a move towards tools that could be used with more precision – as scrapers for woodworking, for instance, or as chisels for working and engraving stone. The cave inhabitants had begun making finer quality stone blades and chisels by 60,000 years ago – and about 10,000 years later they may have been using the tools to make jewellery including that polished green rock bracelet, and what has been described as an ivory tiara.

“The stone industry shows a gradual evolutionary development,” says Kozlikin, but it also shows continuity. Artefacts from each period his team studied were made using stone from the same river beds. Partly because of this, he and his colleagues argue that the tools were all produced by Denisovans. They say this is backed up by evidence of Denisovans occupying the cave throughout these periods, including DNA that was recovered from 200,000-year-old layers, and their remains that were found in cave layers about 100,000 and 60,000 years old. As such, the tools show how Denisovan technology evolved through time.

If these interpretations are correct, this is a remarkable insight into the lives of this almost ghost species. But Bence Viola at the University of Toronto in Canada advises caution. We also know from human remains and DNA in the cave’s sediment that Neanderthals were present there sporadically between about 190,000 and 100,000 years ago. They could have made some of the tools, he says. But that doesn’t necessarily undermine the technological capabilities of Denisovans. Despite their reputation as archaeological enigmas, they probably behaved a lot like Neanderthals and made similar tools, says Viola, “which is exactly why it’s so hard to tell which assemblage was produced by whom”. ■

HOMO FLORESIENSIS: THE DIMINUTIVE HOBBIT

The discovery of a pint-sized hominin on the Indonesian island of Flores in 2003 kicked off a new era in palaeoanthropology. Before that, many fossil hunters had assumed that there was little material evidence of human evolution still to be unearthed. Afterwards, anything seemed possible.

And the “hobbit”, as this new species was quickly dubbed, defied all expectations of what a member of our genus might look like and where it could be found. We now know it wasn’t the only unusual hominin in the neighbourhood.



FROM the start, *Homo floresiensis*, aka the hobbit, has been an evolutionary puzzle. It had a strange mix of features: a short body, unusually long feet, and a surprisingly tiny brain. Those are features that wouldn’t look out of place in an early species of human wandering around Africa about 2 million years ago, when humans first evolved from australopiths. But *H. floresiensis*

lived thousands of kilometres east of Africa, on the Indonesian island of Flores, as recently as 50,000 years ago. What’s more, it seems to have behaved like an advanced human at least in terms of its ability to control fire and cook food.

From the start, some argued that the hobbits were simply short members of our own species. They pointed out that the miniature size of the one skull that has been uncovered could be the result of Down’s syndrome. However, the dominant idea has been that *H. floresiensis* was descended from the larger *Homo erectus*, an extinct human species that once occupied Asia. Ancestors of *H. erectus* were the first humans to stray out of Africa about 1.8 million years ago. The theory is that after members of the big-bodied group reached Flores, they gradually shrunk to just 1 metre tall because of the scarce island resources.

In 2017, the provenance of the mysterious hobbit was turned on its head when a team led by Colin Groves at the Australian National University, constructed its family tree. Previous research had only focused on skull and jaw characteristics but Groves and his team carefully compared skull, jaw, teeth, arm, leg and shoulder fossils with other *Homo species* and with more primitive ancestors. They found that *H. floresiensis* with its primitive, diminutive body type, was far more closely related to *Homo habilis* than to *H. erectus* or *H. sapiens*. This, they said, suggests it came from an ancient lineage and shared a common ancestor with ➤

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H. habilis, a species known to live only in Africa.

The researchers concluded that the hobbit evolved from a mystery ancestor living in Africa over 2 million years ago and belonging to the genus *Australopithecus*. Some members of this ancestral group remained in Africa and evolved into *H. habilis* – the first makers of stone tools. Others moved out of Africa about 2 million years ago – before *H. erectus* did – and arrived in Flores at least 700,000 years ago. “As this ancestor spread through south and south-east Asia and then finally onto Flores, it would have gradually changed, finally becoming *H. floresiensis*,” says Groves.

The hobbit’s ancestors probably died out across Asia when bigger, more complex human species like *H. erectus* and *H. sapiens* later emerged from Africa, Groves says. *H. floresiensis* was probably only able to cling on in Flores for as long as it did because of the island’s isolation. There is no fossil evidence to indicate that *H. erectus* ever made it to the island. However, the hobbit appears to have died out soon after *H. sapiens* left Africa 60,000 years ago and pushed into Asia. It is possible that a clash with our own species spelled the end of the mysterious Indonesian hobbits.

But the story doesn’t end there. In 2019, palaeoanthropologists announced the discovery of another new hominin species in the Philippines. In fact, the first signs that ancient humans had inhabited the island of Luzon came in 2007, when a team co-led by Florent Détroit at the French National Museum of Natural History and Armand Salvador Mijares at the University of the Philippines had discovered a 67,000-year-old hominin foot bone. They tentatively

The tiny “hobbit” appears to have clung on longer on a few islands as bigger species came to dominate

assigned it to our species. Then the team found 12 more fossils – seven teeth, two finger bones, two toe bones and part of a thigh bone – which looked too primitive to belong to *H. sapiens*.

Some of the teeth have been dated as 50,000 years old. This means the fossils are roughly the same age as some of the hobbit remains found about 5000 kilometres to the south on Flores. But the Luzon fossils have distinct features and so belong to a different species, according to Détroit and Mijares. It isn’t yet possible to know for sure whether this species, *Homo luzonensis*, was small in stature like the hobbits because there are so few fossils. The teeth found on Luzon are extraordinarily small though. What’s more, as with *H. floresiensis*, the hand and foot bones are notably similar to those of *Australopithecus*.

The new discovery is likely to intensify the hunt for more extinct human species on nearby islands. Many researchers suspect that ancient hominins lacked the ability to build boats and cross seas on a whim. They suggest it is more likely that they reached islands like Luzon and Flores by accident – perhaps after individuals living along coasts were washed out to sea during storms and deposited on a distant shore. If so, it is possible that small groups of hominins might have been accidentally deposited on other islands in the region and, once isolated, evolved into other new species. ■

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CHAPTER 6

WHAT MAKES US HUMAN?

A detailed, realistic illustration of a human skull in profile, facing right. The skull is rendered in a dark, muted brown color with subtle highlights and shadows that emphasize its anatomical features, including the forehead, eye socket, nose, cheekbone, jaw, and teeth. The skull is positioned behind the main title text, which is overlaid in a large, bold, white sans-serif font.

Most of the traits once thought uniquely human, such as culture and tool use, are found to a lesser extent in other animals. But there are a few that we alone seem to possess, such as complex language.

How and why these evolved can provide unexpected insights into the journey we took to becoming human. Anthropologist **Richard Wrangham** kicks us off with one of our most intriguing traits – our seemingly unique capacity for both good and evil.

ESSAY

THE GOOD (AND BAD) APE

No other animal has a moral sense – and none seems capable of such kindness or such cruelty as humanity. Why is that?

PROFILE RICHARD WRANGHAM

Richard Wrangham is the Ruth B. Moore professor of biological anthropology at Harvard University. He is best known for his work on the evolution of human warfare and the role of cooking in human evolution, and is author of the 2019 book *The Goodness Paradox*

ARE humans, by nature, good or evil? The question has split opinions since people began philosophising. Some, like the followers of Jean-Jacques Rousseau, say we are a naturally peaceful species corrupted by society. Others side with Thomas Hobbes and see us as a naturally violent species civilised by society. Both perspectives make sense. To say that we are both “naturally peaceful” and “naturally violent” seems contradictory, however.

The paradox is resolved if we recognise that human nature is a chimera. The chimera, in classical mythology, was a creature with the body of a goat and the head of a lion. It was neither one thing nor the other: it was both. I argue that, with respect to aggression, a human is both a goat and a lion. We have a low propensity for impulsive aggression, and a high propensity for premeditated aggression. This solution makes both Rousseauians and Hobbesians partially right, but it raises a deeper question: why did such an unusual combination of virtue and violence evolve?

The story of how our species came to possess this unique mixture offers a rich and fresh perspective on the evolution of our behavioural and moral tendencies. It also addresses the fascinating but surprisingly neglected question of how and why our species, *Homo sapiens*, came into existence at all.

Since the 1960s, efforts to understand the biology of aggression have converged on an important idea. Aggression – meaning behaviour intended to cause ➤

SCIENCE PICTURE CO/ALAMY STOCK PHOTO



“Humans have a unique propensity for both virtue and violence”

physical or mental harm – falls into two major types, so distinct in their function and biology that from an evolutionary viewpoint they need to be considered separately. I use the terms “proactive” and “reactive” aggression, but many other word pairs describe the same dichotomy, including cold and hot, offensive and defensive, premeditated and impulsive.

To judge from other relevant animals, a high level of proactive aggression is normally associated with high reactive aggression. The common chimpanzee is the primate species that most often uses proactive aggression to kill its own kind, and it also has a high rate of reactive aggression within communities. The wolf’s proactive aggression against members of its own species is often lethal. As with chimpanzees, although relationships within wolf groups are generally benign and cooperative, they are far more emotionally reactive than dogs are. Lions and hyenas are also wolf-like in these respects.

Something different happened in the human lineage. While proactive aggression stayed high, reactive aggression became suppressed. The evidence, I argue, points to self-domestication being the “something different” that made humans special.

So, how did humans become self-domesticated? Evidence from fossils reveals the process started certainly by 200,000 years ago, and possibly with the first glimmerings of *H. sapiens* a little more than 300,000 years ago. Language-based conspiracy was the key, because it gave whispering subordinates the power to join forces to kill bullies – presumably, alpha males, since men tend to be more violent than women. As

happens in small-scale, traditional societies today, language allowed underdogs to agree on a plan and thereby to make predictably safe murders out of confrontations with intended victims that would otherwise have been dangerous. Genetic selection against the alpha males’ propensity for reactive aggression was an unforeseen result of eliminating the would-be despots. The selection against alpha-male behaviour led to an increasingly calm tenor of life within social communities of *H. sapiens*. Our species is now more Rousseauian than it has ever been.



See later in the chapter for more on the evolution of language

The same ability to perform capital punishment that led to self-domestication also created the moral senses, as Christopher Boehm at the University of South California has argued. In the past, to be a nonconformist, to offend community standards or to gain a reputation for being mean were dangerous adventures; to some extent this is still true today. Rule breakers threatened the interests of the elders – the coalition of males holding power – so they risked being ostracised as outsiders or sorcerers. Nonconformists who refused to change their behaviour were executed. Selection accordingly favoured the evolution of emotional responses that led individuals to feel and display unity with the group. Conformity was vital.

The moral senses of individuals thus evolved to be self-protective to a degree not shown by other

primates. The strongly conformist behaviours produced by the new tendencies provided a safe passage through life, and they had a second effect as well. By reducing competition and selfishness, they promoted behaviour that benefited the group as a whole. The idea that the moral senses evolved to protect individuals from the socially powerful suggests that group selection may be unnecessary for explaining why we are such a group-oriented species.

So what about proactive aggression? A predisposition for premeditated violence was in place in our *Homo* ancestors by at least 300,000 years ago, and perhaps as much as 2 million years ago. How much earlier it was present isn't marked by anything so concrete as domestication, which comes with a syndrome of behavioural and physical characteristics. Based on inferring the behaviour of our ancestors, however, a high propensity for coalitionary proactive aggression probably operated at least through the 2 million or more years of the Pleistocene.

The reason for this claim is the antiquity of hunting. *Homo erectus*, the first ancestor of *H. sapiens* that was committed, like us, to living on the ground, evolved around 2 million years ago. Cut marks that *H. erectus* left on meat-bearing bones show that they butchered animals the size of large antelope. By 1 million years ago, ambush hunting is suggested (humans repeatedly reused a site of that age at Olorgesailie, Kenya, a place where animal prey were limited to narrow travel routes and could therefore be killed easily); this implies cooperation and planning too. However, only with *H. sapiens* and Neanderthals, in the past few hundred

thousand years, have we found sufficient evidence that hunting had clearly become premeditated: using spears, catching small animals apparently by setting snares, and hunting from elevated positions. So a conservative interpretation might limit proactive hunting to the Mid-Pleistocene.

After our ancestors became good hunters, they could have killed strangers; hunting is a transferable skill. Hunting and simple war both require searching and safe dispatching, and both benefit from long-distance travel and well-honed coordination. Wolves, lions and spotted hyenas use coalitionary proactive aggression not only to get food but also to kill rivals in other groups. Chimpanzees are also social hunters and killers of their own species. Bonobos, by contrast, aren't known to be social hunters (despite their liking of meat) and, to date, haven't shown clear evidence of planned aggression. Among humans still living in small-scale societies, there is a similar association: societies relying more on hunting tend to have more frequent war.

For all these reasons, human hunting of prey seems likely to have been associated with the ability to kill rivals in neighbouring groups 2 million years ago. The origins of proactive violence may be far deeper, however. The killing of strangers probably went back 7 million years or more to our common lineage with chimpanzees and bonobos, when our central African ape ancestor was probably a chimpanzee-like hunter and killer. Much as chimpanzees and wolves attack strangers, once our ancestors had achieved the ability to kill safely, a motivation to kill strangers would ➤

THE CAVE ART CODE

probably have been present too. There seems no reason to excuse our ancestors from the links between hunting and violence found in other animals.

Regardless of when coalitionary proactive aggression began against strangers, killing within groups was limited until humans developed a superior language ability. Much changed after individuals became able to share complex ideas with one another. People could then form alliances based on shared interests that they could articulate. With the arrival of planned and communally approved executions, the bullying by an alpha male was exchanged for the subtler tyranny of the previous underdogs. The newly powerful coalitions of males became the set of elders who would rule society – a system that largely continues today, albeit more with laws, threats and imprisonment than with execution.

Both our “angelic” and “demonic” tendencies, therefore, depended for their evolution on the sophisticated forms of shared intentionality made possible by high-level language – an ability that undoubtedly also contributed to much pro-social behaviour. A chimpanzee-style form of shared intentionality launched the process at least 7 million years ago. It took the mysterious dawning of an improved language facility, sometime between 500,000 and 300,000 years ago, to shake us into a new world. Language created the chimeric aspects of our personality, high killing power lying alongside reduced emotional reactivity. A unique cognitive ability gave us a uniquely contradictory psychology: a predisposition for both virtue and violence. ■

Perhaps the most iconic inheritance from our ancestors is their cave art, with breathtaking paintings of bulls, horses and bison that are tens of thousands of years old readily springing to mind. But as far as the development of our species is concerned, the real interest might lie in the smaller, geometric symbols frequently found alongside these paintings. Far from being random doodles, they could represent a fundamental shift in our ancestors’ mental skills.



Etched deer teeth
from Saint-Germain-
de-la-Rivière, France

WHEN she first saw the necklace, Genevieve von Petzinger feared the trip halfway around the globe to the French village of Les Eyzies-de-Tayac had been in vain. The dozens of ancient deer teeth laid out before her, each one pierced like a bead, looked roughly the same.

It was only when she flipped one over that the hairs on the back of her neck stood up. On the reverse were three etched symbols: a line, an X and another line.

Von Petzinger, a palaeoanthropologist from the University of Victoria in Canada, is spearheading an unusual study of cave art. The first formal writing system that we know of is the 5000-year-old cuneiform script of the ancient city of Uruk in what is now Iraq. But it and other systems like it – such as Egyptian hieroglyphs – are complex and didn’t emerge from a vacuum. There must have been an earlier time when people first started playing with simple abstract signs. For years, von Petzinger has wondered if the circles, triangles and squiggles that humans began leaving on cave walls 40,000 years ago represent that special time in our history – the creation of the first human code.

If so, the marks are not to be sniffed at. Our ability to represent a concept with an abstract sign is something no other animal, not even our closest cousins the chimpanzees, can do. It is arguably also the foundation for our advanced, global culture.

The first step to check her theory was to fastidiously

document the signs, their location, age and style, and see if any patterns emerged. For this, von Petzinger would have to visit as many caves as she could: archaeology’s focus on paintings of animals meant the signs were often overlooked in existing records.

It wasn’t easy or glamorous work. Gaining access to caves in France, where a lot of Stone Age art is located, can be devilishly complicated. Many are privately owned and sometimes jealously guarded by archaeologists. For the full set of symbols, von Petzinger also had to visit many obscure caves, the ones without big, flashy paintings. At El Portillo in northern Spain, all she had to go on was a note an archaeologist made in 1979 of some “red signs”; no one had been back since. At first, von Petzinger couldn’t even find the entrance. Eventually, she noticed a tiny opening at knee level, trickling with water. “Thank God I’m not claustrophobic,” she says. After 2 hours sliding through mud inside the mountain, she found two dots painted in pinkish ochre.

Between 2013 and 2014, von Petzinger visited 52 caves in France, Spain, Italy and Portugal. The symbols she found ranged from dots, lines, triangles, squares and zigzags to more complex forms like ladder shapes, hand stencils, something called a tectiform that looks a bit like a post with a roof, and feather shapes called penniforms. In some places, the signs were part of bigger paintings. Elsewhere, they were on their own, like the row of bell shapes found in El Castillo in northern Spain, or the panel of 15 penniforms in Santian, also in Spain.

Perhaps the most startling finding was how few ➤

signs there were – just 32 in all of Europe. For tens of thousands of years, our ancestors seem to have been curiously consistent with the symbols they used. This, if nothing else, suggests that the markings had some sort of significance. “Of course they mean something,” says French prehistorian Jean Clottes. “They didn’t do it for fun.” The multiple repetitions of the P-shaped claviform sign in France’s Niaux cave “can’t be a coincidence”, he argues.

Thanks to von Petzinger’s meticulous logging, it’s now possible to see trends – new signs appearing in one region, sticking around for a while before falling out of fashion. Hand stencils, for example, were fairly common in the earliest parts of the Upper Palaeolithic era, starting 40,000 years ago, then fall out of fashion 20,000 years later. “You see a cultural change take place,” says von Petzinger. The earliest known penniform is from about 28,000 years ago in the Grande Grotte d’Arcy-sur-Cure in northern France, and later appears a little to the west of there before spreading south. Eventually, it reaches northern Spain and even Portugal. Von Petzinger believes it was first disseminated as people migrated, but its later spread suggests it then followed trade routes.

The research also reveals that modern humans were using two-thirds of these signs when they first settled in Europe, which creates another intriguing possibility. “This does not look like the start-up phase of a brand-new invention,” von Petzinger wrote in her 2017 book, *The First Signs: Unlocking the mysteries of the world’s oldest symbols*. In other words, when modern humans first started moving into Europe from Africa, they must have brought a mental dictionary of symbols with them.

That fits well with the discovery of a 70,000-year-old block of ochre etched with cross-hatching in Blombos cave in South Africa. And when von Petzinger looked through archaeology papers for mentions or illustrations of symbols in cave art outside Europe, she found that many of her 32 signs were used around the world (see diagram, right). There is even tantalising evidence that an earlier human, *Homo erectus*, deliberately etched a zigzag on a shell on Java some

500,000 years ago. “The ability of humans to produce a system of signs is clearly not something that starts 40,000 years ago. This capacity goes back at least 100,000 years,” says Francesco d’Errico from the University of Bordeaux, France.

Nonetheless, something quite special seems to have happened in ice age Europe. In various caves, von Petzinger frequently found certain symbols used together. For instance, starting 40,000 years ago, hand stencils are often found alongside dots. Later, between 28,000 and 22,000 years ago, they are joined by thumb stencils and finger fluting – parallel lines created by dragging fingers through soft cave deposits.

ETCHED TEETH

These kinds of combinations are particularly interesting if you’re looking for the deep origins of writing systems. Nowadays, we effortlessly combine letters to make words and words to make sentences, but this is a sophisticated skill. Von Petzinger wonders whether the people of the Upper Palaeolithic started experimenting with more complex ways of encoding information using deliberate, repeated sequences of symbols. Unfortunately, that’s hard to say from signs painted on cave walls, where arrangements could be deliberate or completely random. “Demonstrating that a sign was conceived as a combination of two or more different signs is difficult,” says d’Errico.

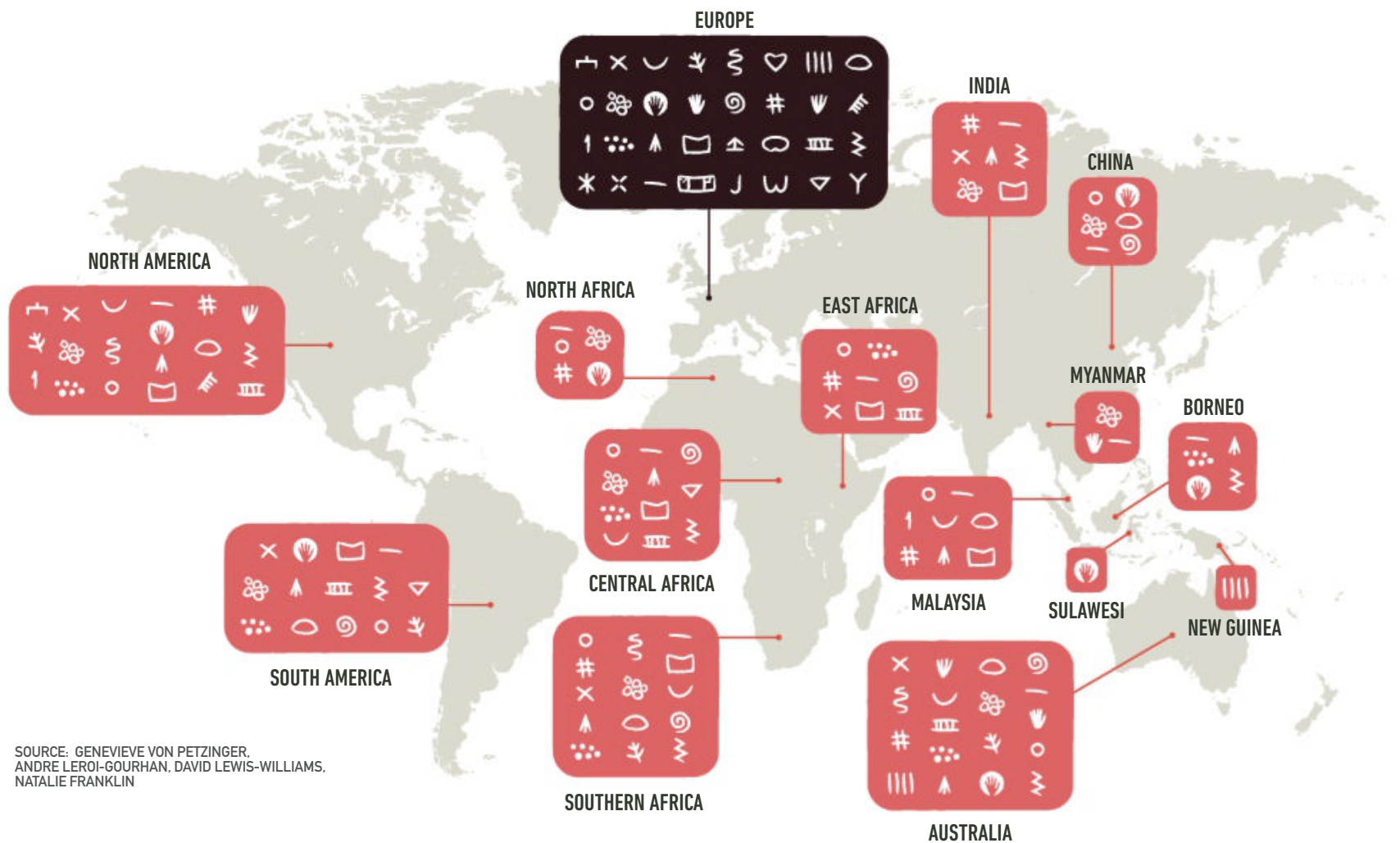
It was while she was grappling with this conundrum that von Petzinger found out about the necklace of red deer teeth. It was found among other artefacts in the grave of a young woman who died some 16,000 years ago in Saint-Germain-de-la-Rivière, in south-west France. From a description in a book, von Petzinger knew that many of the teeth had geometric designs carved into them. So she travelled from Canada to the National Museum of Prehistory in Les Eyzies-de-Tayac, where the teeth were held, in the hope that they might be a missing piece of her puzzle.

The moment she flipped the first one, she knew the trip had been worthwhile. The X and straight lines were symbols she had seen together and separately on

CONSISTENT DOODLES

The symbols seen on relics from Stone Age Europe are also found in caves throughout the rest of the world.

The similarities suggest the marks are more than just random scribbles



various cave walls. Now here they were, with the X sandwiched between two lines to form a compound character. As she turned each tooth over, more and more decorations were revealed. In the end, 48 were etched with single signs or combinations, many of which were also found in caves.

Whether or not the symbols are actually writing depends on what you mean by “writing”, says d’Errico. Strictly speaking, a full system must encode all of human speech, ruling the Stone Age signs out. But if you take it to mean a system to encode and transmit information, then it’s possible to see the symbols as early steps in the development of writing. That said, cracking the prehistoric code may prove impossible. “Something we call a square, to an Australian Aborigine, might represent a well,” says Clottes.

For d’Errico, we will never understand the meaning of the symbols without also considering the animal depictions they are so often associated with. “It is clear that the two make sense together,” he says. Similarly, cuneiform is composed of pictograms and counting tallies. A ration, for instance, is represented by a bowl and human head, followed by lines to denote quantity.

Von Petzinger points out another reason to believe the symbols are special. “The ability to realistically draw a horse or mammoth is totally impressive,” she says. “But anybody can draw a square, right? To draw these signs you are not relying on people who are artistically gifted.”

In a sense, the humble nature of such shapes makes them more universally accessible – an important feature for an effective communication system. “There’s a broader possibility for what they could be used for, and who was using them.”

More than anything, she believes the invention of the first code represents a complete shift in how our ancestors shared information. For the first time, they no longer had to be in the same place at the same time to communicate with each other, and information could survive its owners.

The quest is far from over. Von Petzinger plans to expand her Stone Age dictionary by adding in the wealth of signs on portable objects, in caves on other continents and maybe even those found beneath the waves. “We only have part of the picture now. We are on the cusp of an exciting time,” she says. ■

THE POWER OF LANGUAGE

Language is our most versatile tool. It can transmit information about the past, present and future, formalise ideas, trigger action, persuade, cajole and deceive. Without language, human society would have been impossible.

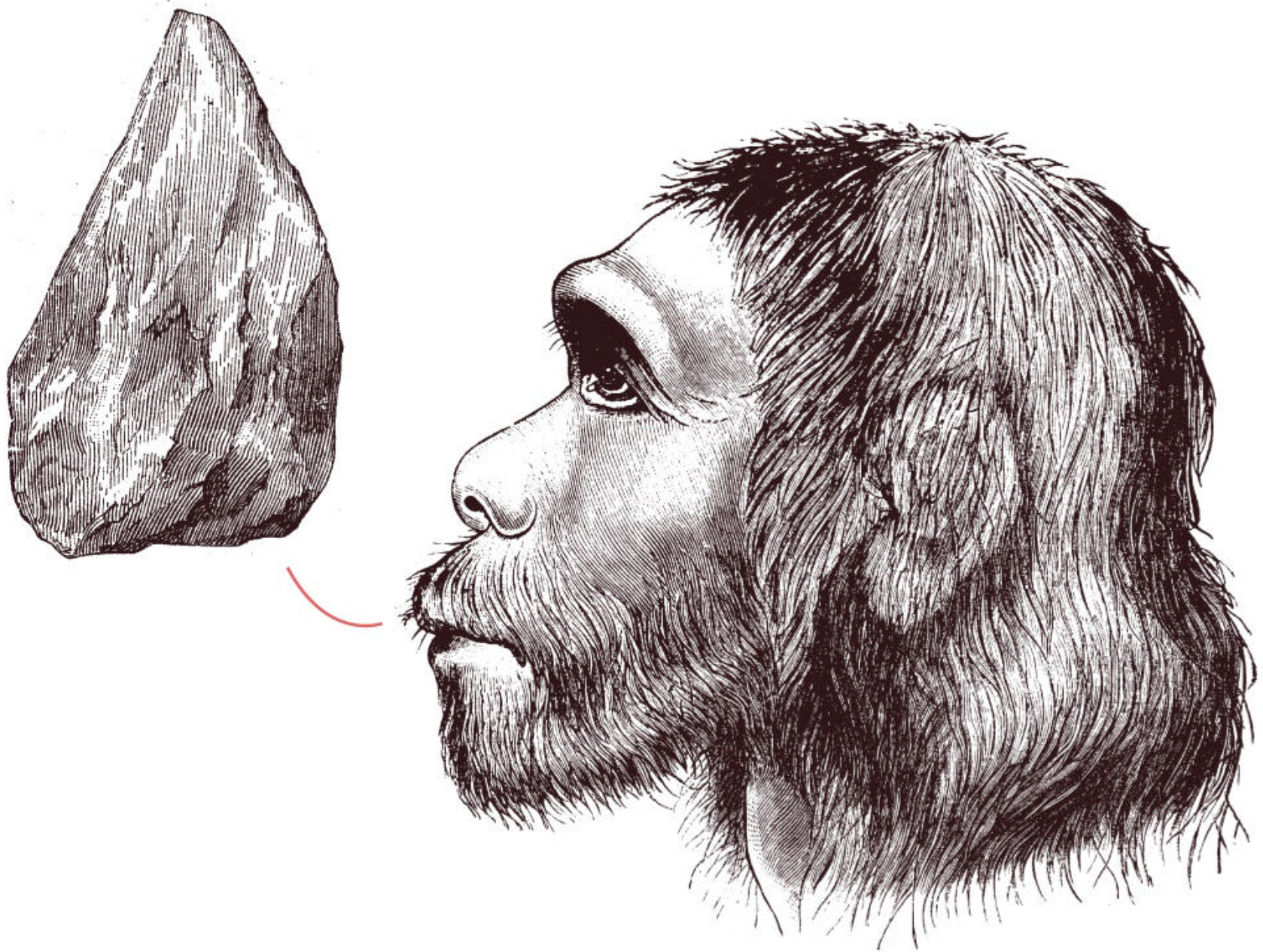
By piecing together clues from anatomy and genetics, we are starting to see when language emerged. The real surprise that story contains is that we may not have been the only communicative hominin.

A

T LEAST since biblical times, people have puzzled over the origins of language. It is, after all, one of the few traits that distinguish humans from all other animals. Even among the hundreds of other primate species, not one has a communication system that comes close to it in its flexibility and infinite range of expression.

Unfortunately, the story of how language evolved is written in invisible ink. The archaeological record can only offer circumstantial evidence of language until writing began just a few thousand years ago. Given the dearth of hard evidence, some researchers have claimed that language arrived rapidly 40,000 years ago. As we have seen, that was when there was a creative explosion of cave paintings and symbolic culture, demonstrating the abstract thinking that language requires.

This explanation was never wholly convincing, however. Humans had already migrated and dispersed



into separate groups by this point, so it would have required a simultaneous cognitive shift in all the populations across the globe.

Sure enough, accumulating evidence about the evolution of key anatomical changes that made us capable of speech leaves little doubt that language has far deeper roots. For a start, other great apes have large air sacs in the throat. These help them make booming calls to scare off rivals, but inhibit the production of the distinct vowel sounds crucial to human speech, according to acoustic simulations by Bart de Boer at the Free University of Brussels in Belgium. Our earliest ancestors had such sacs, but they aren't found in *Homo heidelbergensis*, which evolved 700,000 years ago, around the time when our lineage split from that of the Neanderthals.

Both Neanderthals and modern humans also show a large number of nerve pathways from the brain, through the spine, to the diaphragm and the muscles between the ribs. These provide the refined breath control necessary for precise vocalisations. In addition,

both species have characteristic changes to part of the inner ear, giving greater sensitivity to sound frequencies within the range of the human voice, which is an essential adaptation allowing subtle changes in utterances to convey different meanings.

Then there is the *FOXP2* gene, which influences the brain's wiring and plasticity in areas controlling speech. It is widespread in mammals, but we carry a version that enables us to make the finely controlled movements of our face and mouth required for coherent speech. Neanderthals share a very similar version of the gene, which suggests they, too, were capable of complex articulation.

Given these converging findings, de Boer and others are now convinced that speech of some kind had emerged by at least 500,000 years ago. It may even have started hundreds of thousands of years before that, they argue, when our ancestors first began displaying more sophisticated cooperative behaviours – possibly 2 million years ago or more when stone tools imply people were hunting. Some experts go so far ➤

as to say that we are bound to find degrees of language and speech going back to *Homo erectus* because language and speech arise from a complex mix of physical, social and cultural influences that evolved in a piecemeal fashion. “*Homo erectus*’s hunting and tool-making abilities indicate some kind of advanced communication system,” says Stephen Levinson at the Max Planck Institute for Psycholinguistics in the Netherlands.

Establishing exactly what pushed us along that evolutionary path has been much harder. Most ideas fall into one of three camps. Charles Darwin provided the first – and most provocative. In *The Descent of Man*, he argued that human ancestors passed through a kind of musical protolanguage. Like bird song, these calls had no specific meaning, but were used by males to attract mates. Our vocal flexibility emerged through sexual selection, with competing males developing more complex songs to beat their rivals. Only later, as human intelligence grew, did those sounds slowly become associated with certain meanings.

Darwin pointed out that another group of primates – gibbons – sing to attract mates. And modern science offers some hints of an intimate connection between language and music in humans. Brain scans, for instance, reveal that they are processed by overlapping neural networks. But evidence that language and music emerged through sexual selection is weak, since you would expect to see large sex differences in these abilities as a result. There are other possibilities, however. Perhaps the driving force wasn’t male display, but an equal duet between mates, or even

singing by parents to calm their babies.

Nevertheless, many researchers don’t buy these arguments. Instead, some propose a gestural protolanguage in which the first language-like communication arose through hand movements. The idea is attractive for many reasons. It might explain why all humans, including those who are blind, move their hands as they talk, often without realising they are doing so. Similarly, the spontaneous emergence of sign languages among groups of hearing and speech-impaired people indicates an instinct to use our hands when our voices fail us.

Non-human primates can be surprisingly dextrous with their hands and some, in captivity, have even been taught to communicate using complex signs, but tend to find it harder to learn to reproduce specific sounds. Gestures may therefore have been a much easier means of communicating ideas at the beginning of language evolution. That would have prepared our brains for some of the challenges of language, such as the capacity to connect symbols with meaning, without making huge demands on our primitive voice boxes.

As compelling as these arguments are, the gestural protolanguage can’t neatly explain why we made the switch to primarily vocalised language. That question brings us to the third idea. The notion that language first emerged through onomatopoeia – or imitating the sounds of things – is perhaps the most intuitive of the three possibilities. After all, even children will mimic a neigh or a howl, say, to signify a horse or a wolf. Yet historically, this option had been the underdog, thanks to a couple of seemingly insurmountable issues.

“As human intelligence grew, slowly sounds were associated with meaning”

First, it requires a talent for vocal mimicry. Yet our early ancestors lacked the anatomical and neural adaptations needed for controlled vocalisations. However, it is now emerging that non-human primates have more breath control and vocal flexibility than was thought. Some orangutans can learn to whistle, for instance, and reproduce sounds of a certain pitch. This suggests that our early ancestors may have been capable of crude imitation without too many anatomical changes.

A second objection is that onomatopoeia is too limited to form the basis of a protolanguage. How would our ancestors have signalled silent concepts, such as a particular plant or tool, or something more abstract, like directions to a river? What sound would they use to represent a quiet animal like a rabbit? Hand signs, by contrast, could outline the shape of something or its means of movement – another argument for the idea that gesture came before speech.

But recent research suggests mimicry is more versatile than we might assume. Gary Lupyan at the University of Wisconsin-Madison and Marcus Perlman at the University of Birmingham, UK, set up a competition in which participants had to convey a range of concepts – such as “cook”, “gather”, “knife” or “fruit” – using made-up vocalisations. The scientists then played the recordings to a new set of participants, who had to guess the meanings. Contrary to expectation, they performed far better than chance, suggesting that some inventive onomatopoeia (such as the “whooshing” of a blade) can communicate a much wider range of concepts than once imagined.

With so many pros and cons for each hypothesis of protolanguage, we may seem no closer to finding an answer. But what if all three ideas contain elements of truth? After all, several of the 7000 or so languages spoken today – including some of Australia’s Aboriginal languages and Paamese in Vanuatu – use elements of song, hand signs, imitated sounds and words interchangeably. So perhaps, instead of offering competing explanations, these three ideas might work together to provide a unified theory of the origin of language. That is exactly what anthropologist Jerome Lewis of University College London proposes.

Like Darwin, Lewis believes singing was the first step to freeing up our vocal cords. In place of sexual selection, however, he suggests it emerged for protection. This idea is inspired by his work with Bayaka societies in central Africa, where people take turns to sing all night to ward off predators. Their intertwining voices, singing at different pitches, make the group sound larger, and potentially more dangerous, to animals in the surrounding forest. Similar behaviour has been found among the San people in southern Africa and Indian forest societies, he says.

Lewis suggests that singing became used for defence after our ancestors descended from the trees. “Trees offer a very secure environment for avoiding large predators,” he says. When we started to walk upright and came into savannah-like landscapes, we would have been vulnerable to a frightening array of large cat predators, says Lewis. The first songs would have sounded very different from the refined music we sing today, ➤

but chanting in a chorus would still scare away animals and help protect vulnerable groups. “And this business of vocalising and changing tones to disguise numbers would have led to the sort of vocal dexterity that is crucial to the evolution of more sophisticated vocal boxes and speech articulators,” he says.

This, in turn, would have enabled a growing talent for mimicry, which might have aided hunting. Modern hunter-gatherers often imitate the sounds of forest animals to draw their prey towards them, says Lewis. They also use vocalisations such as bird noises to locate different group members in the forest as they coordinate movements. Employing mimicry in hunting would have given our ancestors an immediate evolutionary advantage. It would also have established the idea that a voiced sound can represent something meaningful. People could then have used those same sounds during storytelling and mimed performances, perhaps to teach novices how to hunt. “Re-enactments play a crucial role in transmitting the sort of knowledge you require for collective hunting,” says Lewis.

This, in his view, was the tipping point. Once pantomimed communication arose, the sounds and gestures could quickly become more structured and stylised, eventually establishing an agreed lexicon between speakers that resembled modern language. There is substantial evidence to back up this story. Various lab experiments have asked participants to use gestures and improvised vocalisations to communicate ideas to successive groups. As these get passed from person to person, they become more systematic, a process that appears to make them more efficient and easier for new speakers to learn. Likewise, in communities where people who are hearing and speech-impaired haven’t been taught a recognised sign language, their DIY signing initially lacks formal grammatical structures. However, over just a couple of generations, more standardised rules emerge.

This still leaves the question of why this unique ability for language hasn’t evolved in other animals.

After all, musicality, gesture and mimicry aren’t unique to humans. But there is one feature that clearly separates us from other animals, the sophistication of our symbolic and cooperative social behaviour. Humans are the only species that routinely exchanges favours, goods and services with others outside their immediate family. We have an elaborate division of labour, we specialise at tasks and then trade our products with others. And we have learned to act in coordinated ways outside the family unit, such as when a nation goes to war or people combine their efforts to build a bridge.



There’s more on human cooperation at the start of this chapter

We take the complexity of our social behaviour for granted, but all these actions rest on the ability to negotiate, bargain, reach agreements and hold people to them. This requires a conduit – like a modern USB cable – to carry complex information back and forth between individuals. Language is that conduit.

Some social insects – ants, bees and wasps – have a level of cooperation without language. But they tend to belong to highly related family groups, genetically programmed to act largely for the good of the group. Human societies must police anyone who tries to take advantage. With words and symbols, we can expose them as cheats and tarnish their reputations. We can lavish praise on those worthy of it, whose reputations will be elevated even among those they have never met: words can travel further than a single action. All these complicated social acts require more than the grunts, chirrups, odours, colours and roars of the rest of the animal kingdom. They tell us why we and we alone have language: our particular brand of sociality could not exist without it. And what’s sure is that without it, our intriguing, complex, ever-evolving human story could never have been told. ■

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